

TECHNICAL REPORT

**Distributed energy resources connection with the grid -
Part 101: Gravity storage connection to the grid**

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Distributed energy resources connection with the grid - Part 101: Gravity storage connection to the grid

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IEC TR 62786-101 has been prepared by IEC Technical Committee 8: System aspects of electrical energy supply. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
8/1814/DTR	8/1832/RVDTR

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.

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.

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.

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1 Scope

This part of IEC TS 62786, which is a Technical Report, provides the principles and general technical characteristics of gravity energy storage systems (**GESS**) connected to the distribution network. It provides a reference for the planning, design, grid connection and operation of **GESS**. It includes an introduction to **GESS**, grid-connection methods, grid-connected characteristics, grid-connected operation and grid-connected testing and so on.

GESS can use liquid or solid mediums for storing or releasing energy. For example, traditional pumped storage utilizes liquid water to achieve energy storing or releasing. This document only focuses on the solid **GESS**, which utilize solid materials (such as concrete, slag, construction waste, etc.) for energy storage. Generally, **GESS** can be classified as vertical **GESS** and slope **GESS**. In the **GESS**, the motor-generators (**MG**) that are directly connected, or indirectly connected to the low voltage (**LV**) or medium voltage (**MV**) distribution network through converters, transfer the energy between the mass blocks and the grid. This document reports the grid-connection method, active power response characteristic, response of active power to frequency, response of reactive power to voltage and test of direct grid connection through synchronous motor-generator (**SMG**), as a supplement to IEC TS 62786-1:2023 [1].

This document describes the interface arrangement for the connection of **GESS** to distribution networks with the nominal frequency of 50 Hz or 60 Hz.

2 Normative references

There are no normative references in this document.

3 Terms, 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>

3.2

gravity energy storage system

system using mass block as energy storage medium, absorbing, storing, converting and releasing electrical energy through power system, generally including motor-generator (**MG**), mass block, mechanical transmission device, mass block carrier device, mass block stacking device, auxiliary electrical equipment and control device, and so on

Note 1 to entry: The **GESS** of various structures use different mechanical devices to lift the mass blocks. In this document, **GESS** are generally classified into vertical **GESS** and slope **GESS**, by the moving paths of the mass blocks. A **GESS** is called a single-machine system if it contains only one **MG**, and a multi-machine system if it contains multiple **MG**.

3.3

motor-generator

electrical machine for **GESS** that can be operated in motoring mode or generating mode

3.4

motoring mode

operating mode in which the motor-generator machine operates as a motor to lift the mass block from a lower position to a higher position

3.5**generating mode**

operating mode in which the motor-generator machine operates as a generator while the mass block is lowered from a higher position to a lower position

3.6**mass block working unit**

minimum combination of equipment that can execute the independent operation for the GESS, generally including the mass block, mechanical transmission device, mass block carrier, auxiliary electrical equipment and control device

Note 1 to entry: The motor-generator in a GESS can be loaded with one or more mass blocks work units.

3.7**mass block**

solid material that stores and releases energy through its height change

3.8**mass block stacking site**

site for stacking mass blocks typically containing the high potential energy storage site and the low potential energy stacking site

3.9**mechanical transmission device**

mechanical component for connecting mass blocks to the motor-generator, including the drag device and the speed change device

3.10**mass block carrier**

device for carrying mass blocks during up and down operation of the mass block

3.11**hot standby status**

state in which the motor-generator has completed the start-up process and is connected to the grid, the mass block being in a position to be put into operation immediately when the system receives a charging or discharging instruction

3.12 Abbreviated terms

AGC	automatic generation control
AVC	automatic voltage control
EMC	electromagnetic compatibility
GESS	gravity energy storage system
LV	low voltage
MV	medium voltage
MG	motor-generator
POC	point of connection
SMG	synchronous motor-generator

4 Introduction to gravity energy storage system

4.1 Basic working principle

At the time of writing, the GESS has different types of structure. It can be classified into the vertical type and the slope type according to the moving trajectory of the mass block, as detailed in Annex A. In the GESS, the electricity can be stored and released by the mass blocks that are held in higher and lower positions, with different gravity potential energy. In the charging operation, the MG of GESS works in motoring mode, absorbing the active power from the power grid. This electric energy is used to lift the mass block from the lower position to the higher position via a mechanical transmission device, effectively converted into the gravity potential energy. In the discharging operation, the mass block that falls from the higher position to the lower position drives the MG to generate electrical power through the mechanical transmission device. The MG in this generating mode converts the gravity potential energy of the mass block into the electricity, and sends it back to the grid. The mechanical transmission device transforms the linear motion of the mass block into the rotational motion of the MG shaft, and it is composed of a speed change device and a driving device. According to existing GESS cases (Annex B), a gearbox, sprocket, belt pulley or other equipment can be chosen as the speed change device, and a steel cable, chain or belt can be chosen as the driving device, as shown in Figure 1. These speed change and driving devices are selected and finalized during the initial design phase of the GESS structure.

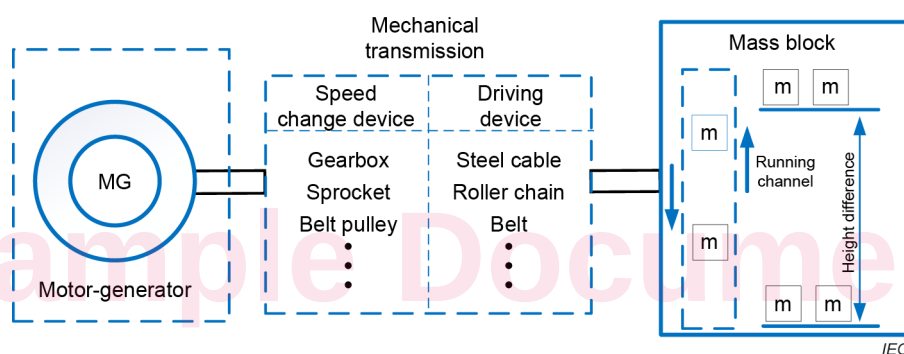


Figure 1 – Illustration of gravity energy storage system

4.2 Relationship between shaft and mechanical power of MG and main design parameters of system

During the operation of GESS, the speed of the mass block in the steady state is fixed, and the input power to the MG from its mechanical section is given by Formula (1).

$$P_{se} = \eta_m n m g v \sin(\theta) \quad (1)$$

where

P_{se}	is the power provided to the MG by the mechanical section,
η_m	is the total efficiency of the mechanical transmission device,
n	is the number of mass blocks moving between the higher position and the lower position,
m	is the mass of a single mass block,
g	is the gravity acceleration,
v	is the constant velocity of the mass block,
θ	is the angle between the path of the mass block and the horizontal plane.

According to Formula (1), with the given speed and the number of mass blocks, the relationship between the input power to the shaft end of the MG, the mass of the mass blocks and the angle is shown in Figure 2.

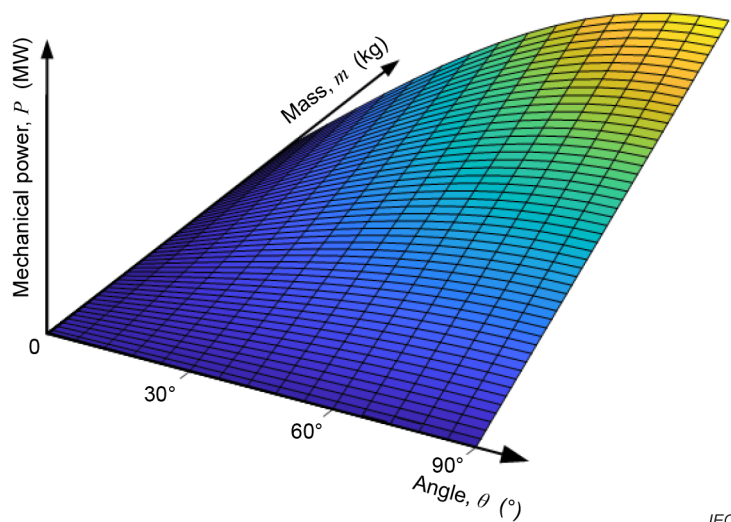


Figure 2 – Relationship between the power at the shaft end of MG, the mass of the mass blocks and the angle

According to Formula (1) and Figure 2, when the angle is fixed, the mechanical power at the shaft end of the MG is proportional to the mass of the mass blocks. When the number of mass blocks is fixed, the power is proportional to the mass of a single mass block. Because the mass of a single mass block in the system is constant, the power has a sinusoidal relationship with the angle.

When two GESS have the same P_{se} , the same total mass but different numbers (n_1 and n_2 , $n_2 > n_1$) of the mass blocks moving between the higher position and the lower position, the mechanical power fluctuation caused by a single mass block in the charging and discharging processes is shown in Figure 3.

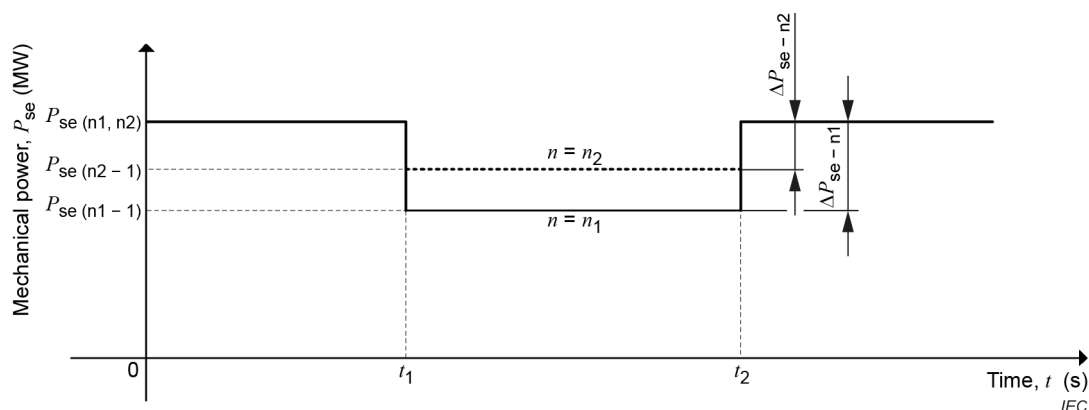


Figure 3 – Mechanical power fluctuation of the MG shaft end caused by a single mass block

According to Figure 3, n affects the percentage of the power fluctuation caused by the switching of a single mass block. It can be observed that as n increases, the power fluctuation of a single mass block decreases ($\Delta P_{se-n2} < \Delta P_{se-n1}$).

4.3 Energy conversion process

4.3.1 General

Despite the various structural forms, all the **GESS** rely on the **MG** to convert the electric active power to the gravity potential energy and vice versa. The following focus on the **GESS** that is directly connected to the grid through the **SMG**, and the processes of charging and discharging are also described. The reactive power can flow between the grid and **GESS** due to the exciter system of the **SMG**.

4.3.2 Energy conversion process in charging operation

The energy conversion during the charging process of **GESS** is shown in **Figure 4**. The **SMG** absorbs electric active power from the grid and drives the mass block upward at the rated speed. With the increase of the height of the mass block, the electric active power is gradually converted into the gravity potential energy of the mass block. The expressions of the kinetic energy and gravity potential energy of the mass block are given by **Formula (2)** and **Formula (3)**.

$$E_k = \frac{1}{2} \sum_{i=1}^N m_i v_i^2 \quad (2)$$

where

E_k	is the total kinetic energy of all the mass blocks in the GESS during up and down operations,
N	is the total number of mass blocks in the system,
m_i	is the mass of the i^{th} mass block,
v_i	is the constant velocity of the i^{th} mass block along the rail,

$$E_p = \sum_{i=1}^N m_i g h_i \quad (3)$$

where

E_p	is the total gravity potential energy stored in the system,
N	is the total number of mass blocks in the system,
m_i	is the mass of the i^{th} mass block,
g	is the gravity acceleration,
h_i	is the moving height of the i^{th} mass block.

When the **GESS** is operating, most of the electric energy absorbed by the **SMG** from the grid is transformed into mechanical energy, including both the gravitational potential energy and the kinetic energy. If the system has no kinetic energy recovery device, this kinetic energy ultimately dissipates into various forms, e.g. as heat. Additionally, energy losses occur within the electrical and mechanical sections, including the copper losses, iron losses, and mechanical friction. Furthermore, energy is required to transport the mass block in the high- and low-potential energy stacking site.