EUNICE

Technical Description of Ptolemaida BESS Project

BATTERY ENERGY STORAGE SYSTEM (BESS) WITH A MAXIMUM POWER INJECTION/ ABSORPTION CAPACITY OF 225MW AND GUARANTEED (USABLE) ENERGY CAPACITY OF 1,350MWh

LOCATION: "WIDER AREA OF LEVAIA", MUNICIPAL UNIT OF AMYNTAIO, MUNICIPALITY OF AMYNTAIO, REGIONAL UNIT OF FLORINA, REGION OF WESTERN MACEDONIA

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1. Introduction

This technical description pertains to the Battery Energy Storage Station (BESS) with a maximum power injection capacity of 225 MW, maximum power absorption capacity of 225 MW, and guaranteed (usable) energy capacity of 1,350 MWh, located in the "Wider Area of Levaia", Municipal Unit of Amyntaio, Municipality of Amyntaio, Regional Unit of Florina, Region of Western Macedonia, Greece.

The project under consideration concerns an Electrical Energy Storage Station (EESS) utilizing electrochemical battery cells. The installation site is planned to be located northwest of the settlement of Levaia, approximately 1.8 km from it, within the administrative boundaries of the Municipality of Amyntaio under the Kallikratis administrative division.

The total area expected to be required for the project is 135,779.33 m². This land is fully suitable and buildable according to current urban planning regulations. It lies outside planning zones, outside settlement boundaries, and outside Urban Control Zones, and it is not subject to the provisions of Law 1337/1983 (Government Gazette 33 A') regarding land and monetary contributions. Nearby, overhead high-voltage transmission lines of the Hellenic Electricity Transmission System (HETS) pass through the area.

According to the current design, the storage system will consist of container-type battery units, with:

- Maximum power injection capacity of 225 MW,
- Maximum power absorption capacity of 225 MW, and
- Guaranteed (usable) energy capacity of 1,350 MWh.

Additionally, for the connection of the battery units, the installation of step-up transformers (LV/MV) is planned. The connection between the battery units and the step-up transformers will be made using XLPE-insulated low-voltage cables, while the MV/LV transformers will connect via underground cables to MV switchgear substations (33 kV), which will house all protection equipment and MV panels for the project.

From the MV switchgear substations, underground medium-voltage lines will connect to a nearby HV/MV substation. More specifically, the project design includes the development of an HV/MV substation for connection to the

Hellenic Electricity Transmission System (HETS), with a total capacity of at least 250 MVA, which will also include all necessary protection and measurement systems. From this substation, a 400 kV overhead transmission line will connect to the HETS.

The Ptolemaida BESS project will be able to store and inject energy into the HETS based on Dispatch Orders from the Energy Control Center of the HETS Operator. Additionally, it will have the capability to participate in all energy markets (day-ahead, intraday, balancing, etc.) and to provide ancillary services such as frequency regulation (FCR, aFRR, mFRR) and voltage regulation (V, cosφ) in real time.

2. Geographical location and administrative affiliation

The project under consideration is located in the wider area of the Levaia settlement of the Municipality of Amyntaio and more specifically 1.8km northwest of the aforementioned settlement.

The BESS will be installed in a plot that has a surface equal to 135,779.33m^2. For the sole purpose of the BESS installation, approximately 37,000m^2 will be covered with equipment.

The location of the site installation, including the polygon, can be viewed in the following screenshot from Google Earth software.

Figure 1. Land polygon of Ptolemaida BESS

Figure 2. EKXA orthophotograph of the BESS station site.

The exact geographical coordinates of the project site are shown below in Table 1.

Table 1. Coordinates of project's polygon

COORDINATES OF INSTALLATION AREA IN EGSA '87 reference system		
POINT	**X**	**Y**
1	303331.34	4502977.41
2	303348.94	4502931.77
3	303355.11	4502923.82
4	303301.49	4502876.68
5	303292.13	4502867.10
6	303281.41	4502855.58
7	303278.64	4502848.89
8	303327.97	4502783.60
9	303309.46	4502770.02
10	303271.09	4502833.35
11	303202.67	4502791.88
12	303244.70	4502722.53
13	303158.85	4502659.20
14	303047.18	4502585.35
15	303006.80	4502560.62
16	302997.04	4502557.28
17	302791.47	4502486.82
18	302557.37	4502373.22
19	302461.97	4502333.26
20	302464.19	4502349.67
21	302407.34	4502380.78
22	302440.21	4502427.04
23	302539.58	4502476.40
24	302649.01	4502565.51
25	302820.00	4502636.95
26	302900.12	4502688.72
27	303159.00	4502855.97

3. Battery Technology

The 225 MW/1350 MWh BESS station will consist of a lithium-ion battery storage system, multiple AC/DC converters and other power and control equipment.

The station utilizes lithium-ion batteries of lithium iron phosphate ($LiFePO_4$ or LFP) technology. The LFP (Lithium ferro-phosphate) battery is a type of Li-ion battery that uses $LiFePO_4$ as cathode material and a graphitic carbon electrode with a metallic backing as the anode. Lithium iron phosphate (LFP) is a popular, cost-effective cathode material for lithium-ion cells known to offer excellent safety and long life, making it particularly suitable for special battery applications requiring high charge currents and stamina. Rechargeable lithium-ion battery technology has its roots in non-rechargeable battery technology, which uses lithium metal cells in the negative electrode. The two electrodes usually have a planar structure in order to facilitate the movement of lithium ions between them. During the charging process, lithium ions are transferred from the positive to the negative electrode through the separator and at the same time there is a flow of electrons from the external circuit. When the battery is discharged the process is reversed.

The term "lithium-ion batteries" does not refer to a specific electrochemical system, but to a set of systems in which there is a flow of lithium ions between the electrodes during charging and discharging. The use of different elements for the electrodes can significantly affect some characteristics of the batteries.

4. BESS Technical Details

The main technical characteristics of the BESS station are described below in Table 2.

Table 2. Main Technical Characteristics

NOMINAL INJECTION POWER	225 MW
NOMINAL ABSORPTION POWER	225 MW
NOMINAL INSTALLED ENERGY CAPACITY	1.645,056 MWh
GUARANTEED (USABLE) ENERGY CAPACITY	1350 MWh

The BESS station will include:

- the switching elements and other protection and control equipment for the internal interconnection and safe operation of the station components,
- earthing & equipotential bonding system and lightning protection system,
- the supervision and control system (SCADA and management infrastructure) of the station components.

4.1. Technical Configuration of the main equipment

The Ptolemaida BESS will be comprised of four hundred twenty (420) prefabricated containers of lithium-ion batteries (Li-ion), type Megapack 2 XL, by TESLA. TESLA Megapack 2 XL is a self-contained bidirectional system that supports charging and discharging. It converts electrical energy into stored (chemical) energy within rechargeable lithium-ion batteries (battery modules) and is designed in a modular manner to support a range of output power. Each Megapack 2 XL contains up to 24 battery modules with integrated inverters, a thermal bay and associated thermal roof accessories, an AC circuit breaker and a set of customer interface terminals and internal control circuit boards. No external auxiliary power supply is required as the Megapack supplies auxiliary power (for control and thermal management needs) from the local AC. Figure 3 shows the Megapack container while Figure 4 shows the individual components that consist the Megapack.

For each container the configuration "EC24" has been selected according to the manufacturer's specifications, giving it a nominal capacity of 3,916.8kWh, i.e. a total of 1,645,056 kWh (420x3,916.8kWh). The nominal power of each battery container is equal to 979.2kW, while the maximum apparent power is 1,320.0kVA. The total installed power capacity of the station equals 411.264,0 kW. The battery packs are certified according to the IEC 62619:2017 και IEC 62933-5-2 standards.

Figure 3. TESLA Megapack 2XL

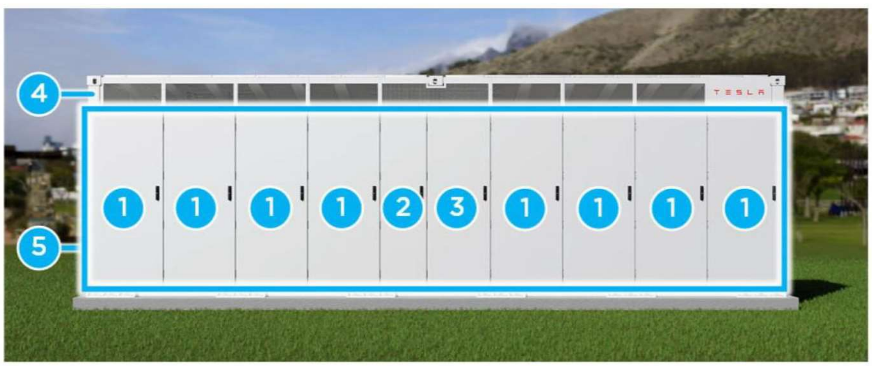

Figure 4. Megapack Overview 1. Battery Module Bays 2. Thermal Cabinet 3. Customer Interface Bay 4. Thermal roof 5. IP66 Enclosure

The typical internal architecture of each Megapack 2 XL assembly is shown in the diagram in Figure 5, where the internal AC interfaces are shown in red and the corresponding DC interfaces are shown in blue. The main components of the Megapack 2 XL are as follows:

- BESS
- Inverter Modules
- Logic: Battery Management System (BMS)
- Power Supply: Megapack 2 XL Auxiliaries' Power Supply
- Auxiliaries
- Breaker: Main Connection breaker

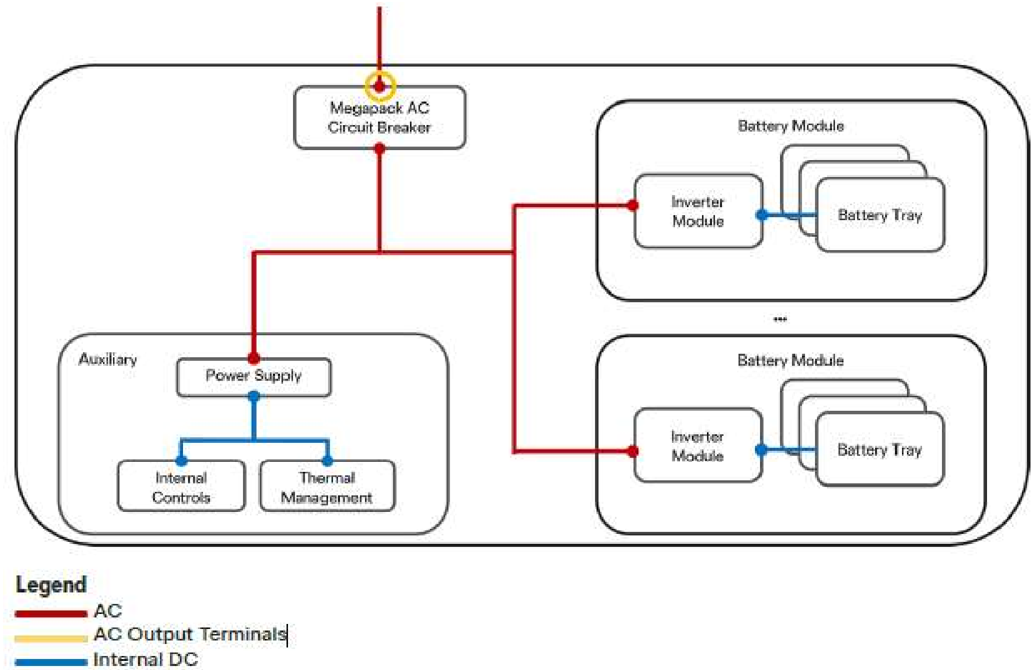

Figure 5. Megapack Internal Architecture

The dimensions of each Megapack 2 XL container are M x W x Y 8800mm x 1650mm x 2785mm and the weight is 38.100kg.

5. Power Conversion System

The bidirectional power converters of the battery system are integrated within the containers as shown in Figure 5. During discharge, the DC output power of the batteries is converted into 50 Hz AC power using power converters, which act as inverters. During charging, the AC mains power is converted into DC power by means of a rectifier operation of the power converters. For this purpose, the integrated power converters operate in the four quadrants. For the converters the setting 'P132' has been selected, i.e. they can handle up to 1,320 kVA per container and operate at a nominal AC voltage of 480 V. In addition, they support Fault Ride Through, anti-islanding protection, Black Start, operation around Vref for voltage control, change of statistics settings, active/reactive power regulation and power factor regulation.

The technical characteristics of the accumulator power converters are listed in Table 3.

Table 3. Main Characteristics of power converters

Maximum Continuous Output Current	Adjustable (Factory Settings)
Overload Capability	120% of nominal current (maximum duration: 10 seconds)
Nominal Alternating Voltage (AC)	480 V
Output Voltage Range	422-552 V AC
Nominal Frequency (Adjustable)	50 ή 60 Hz
Frequency Range	45-66 Hz
Nb of Phases	3
System Topology	Three phases & PE (Protective Earth)
Grounding Topology	Grounded star configuration on the transformer secondary
Adjustable Power Factor	-1 to 1
Total Harmonic Distortion (THD)	< 5 %
Power Regulation Accuracy	< 2 %
Maximum Short-Circuit Current	85 kAIC

6. MV/LV Transformers

A power transformer is installed at the output of every four Megapack containers to raise the voltage to the Medium Voltage level of 33kV. A total of one hundred and five (105) 33/0.48kV transformers, rated at 4.8MVA nominal power, are installed. These transformers are of outdoor type and are mounted on a base. The technical characteristics of the MV/LV transformers are listed in Table 4.

Table 4. Main Characteristics of Power Transformers

Nominal Power	4800 kVA
Nominal Voltage Level on High Voltage Winding	33000 V
Nominal Voltage Level on Low Voltage Winding	480 V
Nominal Frequency	50 Hz
Number of phases	Three (3)
Number of Low Voltage Windings	Two (2)
Winding Connection Type	Dyn11yn11
Inductive reactance	8%

No-Load Losses	3000W
Full Load Losses (75°C)	38500W
Cooling Medium	Oil

Each MV/LV transformer is connected via underground MV cables to a 33kV coupling substation of the station. Each coupling substation is of the roofed type in a prefabricated house and contains all the necessary protection and control devices (MV panels, automatic power switches, voltage and intensity switchboards, etc.). An MV line (single or double circuit) will run from each MV coupling substation to interconnect the substation with the high voltage (400/33kV) substation, where the BESS in question will be connected to the Hellenic Energy Transmission System (HETS).

7. Proposed Method of Connection to the HETS (Hellenic Electricity Transmission System)

The station will be connected to the HETS through a High Voltage/Medium Voltage (HV/MV) substation. It is proposed that the station be connected via the development of a new HV/MV substation, to be constructed within the station's installation site. The substation is proposed to be of an outdoor type (AIS High Voltage Substation), including:

- Two (2) step-up transformers (33 kV/400 kV) with a capacity of 125 MVA each.
- Two fully equipped 400 kV overhead line bays and two transformer bays.
- A Medium Voltage (MV) switchgear assembly.

The 400 kV equipment will be outdoors and include power circuit breakers, disconnectors, voltage and current transformers, lightning arresters, insulators, and other necessary equipment. The MV equipment will include metal-clad cells, housed inside a building, neutral point grounding resistors, an internal substation for auxiliary power supply, and other protection and control equipment.

7.1. Specific Components of the Proposed HV/MV Substation

- **HETS Expansion Works**
  - Outdoor High Voltage Equipment (400 kV)
    - Lightning arresters, wave traps, and coupling capacitors (400 kV).
    - Gas-insulated SF6 GIL lines and SF6-air terminals connecting GIL lines to the overhead phase conductors.
    - Dual overhead phase conductors for connecting the 400 kV transmission line to the GIL lines in the 400 kV bays.
    - Busbars and GIS bays (400 kV), including two-line bays, two transformer bays, one busbar interconnection bay, grounding switches, and voltage transformers. The GIS equipment will use SF6 gas insulation with two busbars.
  - Equipment Inside Building A
    - Protection, control, and measurement systems for the above equipment.
    - Communication equipment to connect the substation to the remote Energy Control Center of the TSO, using a Digital Control System
    - Auxiliary low-voltage (LV) power supply units.
    - Communication systems for the EESS connection to the ECC.
- **User Installation Works**
  - Outdoor Power Transformer Equipment (33/400 kV) and MV (33 kV):
    - Two (2) power transformers (400/33 kV), each with a nominal capacity of 150 MVA.
    - One (1) 33/0.4 kV service transformer with an indicative capacity of 250 kVA, to supply auxiliary power to the substation.
    - Grounding resistors for the 33 kV system.
    - 33 kV lightning arresters.
  - MV Equipment (33 kV) Inside Building B:
    - MV busbars and bays developed in SF6-insulated metal-clad panels (Gas Insulated Switchgear).
    - Auxiliary LV power supply units.
    - Protection, control, and measurement equipment (DCS No. 2).
    - Additional facilities

- Water supply and fire protection pump stations and a backup generator for the entire substation will be installed in two separate enclosures.

7.2. Station Management System

The station will be equipped with a comprehensive digital management and control system, tailored to the technology and specific requirements of Li-ion battery energy storage stations. This management system collects data from individual points within the battery array, ensuring compatibility with the System Operator's commands while optimizing internal management. The primary objectives are to enhance safety, efficiency, and battery lifespan.

The station's Energy Management System (EMS) will include a full suite of features and software applications, enabling:

- Direct participation of the station in market operations,
- Integration into the SCADA system and Automatic Generation Control (AGC) of the Hellenic Independent Power Transmission Operator (IPTO),
- Frequency response capabilities, and more.

Through the Energy Management System (EMS), the station will communicate with the Control Center of the interconnected system, under IPTO's responsibility. From this center, the station's operation will be monitored, and any command from the TSO will be transmitted.