NOTE: This draft is for informational purposes only. Final content is contingent upon final review and confirmation of certifications.

POWERPACK SYSTEM 2
SITE DESIGN MANUAL

Nov. 13, 2016

DRAFT B - Rev. 1.00

PRODUCT SPECIFICATIONS

All specifications and descriptions contained in this document are verified to be accurate at the time of printing. However, because continuous improvement is a goal at Tesla, we reserve the right to make product modifications at any time.

The images provided in this document are for demonstration purposes only. Depending on product version and market region, details may appear slightly different.

ERRORS OR OMISSIONS

To communicate any inaccuracies or omissions in this manual, please send an email to: energymanualfeedback@tesla.com.

MADE IN THE USA

1. Introduction

This document provides the necessary details to install a Tesla Powerpack System. The **Powerpack System 2** is a modular, fully integrated, AC-coupled industrial Energy Storage System (ESS).

NOTE: Any deviation from what is specified in this installation manual must be submitted to Tesla in writing in advance for approval.

An installation consists of a level pad and three types of enclosure:

- Rechargeable lithium-ion battery pack cabinets (**Powerpack Unit**)
- Bi-directional power conversion system (**Powerpack Inverter**)
- **Powerpack Controller** (vertically mounted enclosure that controls system commands)

The bi-directional inverter, which can be configured as grid-connected and/or grid-forming, converts power for rechargeable lithium-ion battery packs (Tesla Powerpack Units). Powerpack Inverters have a nominal rating power between 50 and 625 kVA, depending on the installed number of power stages and grid voltage.

One Powerpack Inverter, and 1-20 Powerpack Units assigned to that inverter, make up an **inverter block**. The number of Powerpack Units per inverter can be scaled for energy, to meet the required hour ratings of the system (for example two, three, or four hours). The number of inverter blocks can be scaled to meet the required power ratings of the system (for example, 1 MW, 5 MW, or 50 MW).

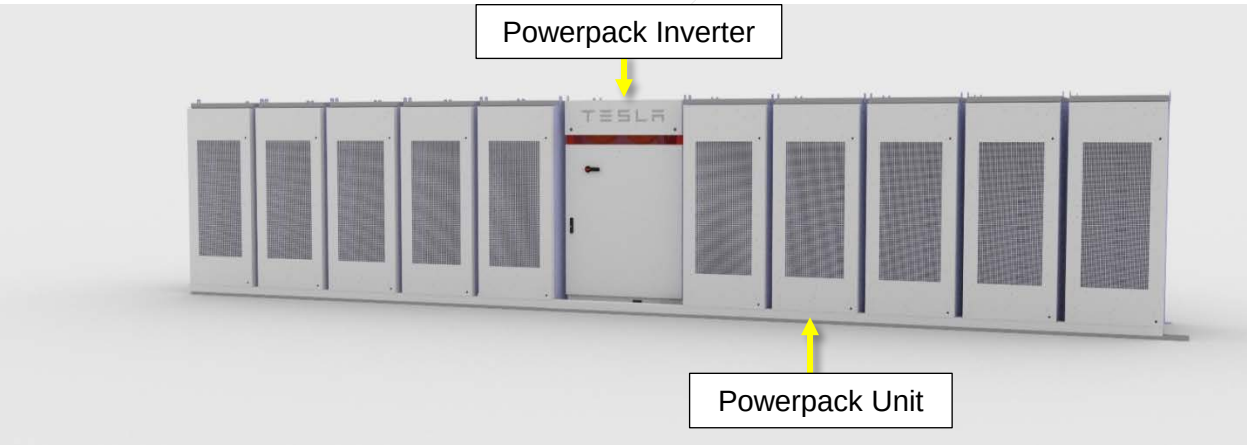

Figure 1: Rendering of a 500 kVA 4-Hour Inverter Block

NOTE: It is also possible to configure a Powerpack System using Powerpack 1.5 Units and a Powerpack Inverter, for a system that operates at 900 V (like the Powerpack System 2) but with a per-Powerpack Unit energy rating of 95 kWh instead of the Powerpack 2's 210 kWh energy rating. This is called Powerpack System 1.5. This manual, and the *Powerpack System 2 Site Design Manual*, note where 1.5 is different from 2.

Pod

Cylindrical lithium-ion battery **cells**, the smallest non-divisible component of the Powerpack System, are assembled in serial and parallel arrays. Cell arrays are assembled into battery **modules** of several kWh each, similar to the modules used in Tesla's electric vehicles. Modules are assembled into a **Pod** (Figure 2), which is the smallest field replaceable unit. The Pod integrates one or more battery modules, an isolated DC/DC converter, traditional Battery Management System (**BMS**) functions, and liquid thermal management in a rugged dust- and waterproof IP67 steel enclosure.

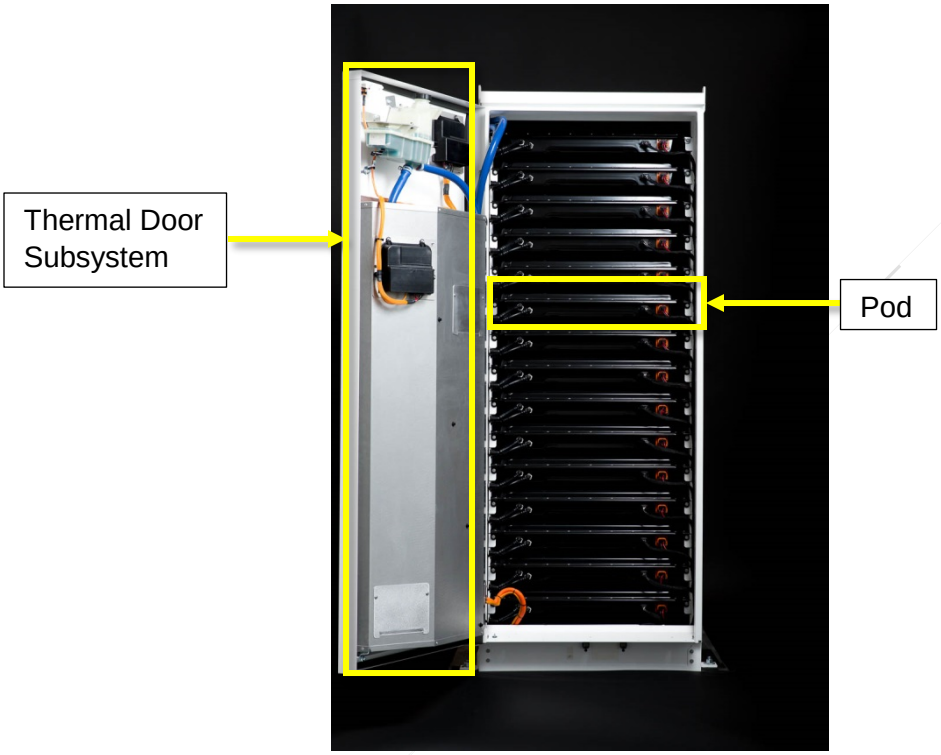

Figure 2: Powerpack Unit

Powerpack Unit

The Powerpack Unit is a standalone NEMA 3R enclosure containing 16 Pods connected in parallel with a single DC and communications output connection (Figure 2). Pods are pre-wired within the Powerpack Unit and do not require any field assembly or adjustments. Pods must only be replaced by Tesla service personnel.

Thermal Door Subsystem

The thermal management system is housed on the inner face of the Powerpack Unit door. The door includes a radiator and pump system that circulates about 26 L of a 50/50 ethylene glycol / water coolant mix through the battery to maintain thermal control. The thermal subsystem also includes 400 g of R134a (1,1,1,2-Tetrafluoroethane) refrigerant in a sealed system. All Powerpack Units ship with the necessary coolants and refrigerants included. The thermal door subsystem is a fully closed loop system.

Powerpack Unit Enclosure

The Powerpack Unit door includes two latches that require a special tool to unlock, limiting access to authorized personnel only (Figure 3).

Figure 3: Powerpack Unit Security Latches

NOTE: The Powerpack Unit includes an Enable circuit as a safety feature. Opening the door of any Powerpack Unit shuts down all Powerpack Units within an inverter block.

Powerpack Inverter

Each inverter block contains a Powerpack Inverter that converts DC power to AC power (discharge mode) or AC power to DC power (charge mode). It contains four main sections: Customer Connection, Power Stages, Low Voltage, and Thermal Management.

Customer Connection Section

The lower left side of the Powerpack Inverter enclosure (Figure 4) is the Customer Connection section. It contains:

- The **interface board**, a circuit board serving as a communications gateway between the Powerpack Inverter and Powerpack Units, with CAN communication harness terminations for the Powerpack Units and Ethernet terminations for the Cat5e/6 cable to the Powerpack Controller
- DC bus bars with fuses protecting each Powerpack Unit DC wire harness
- The AC bus bar for connecting the inverter to the site panel

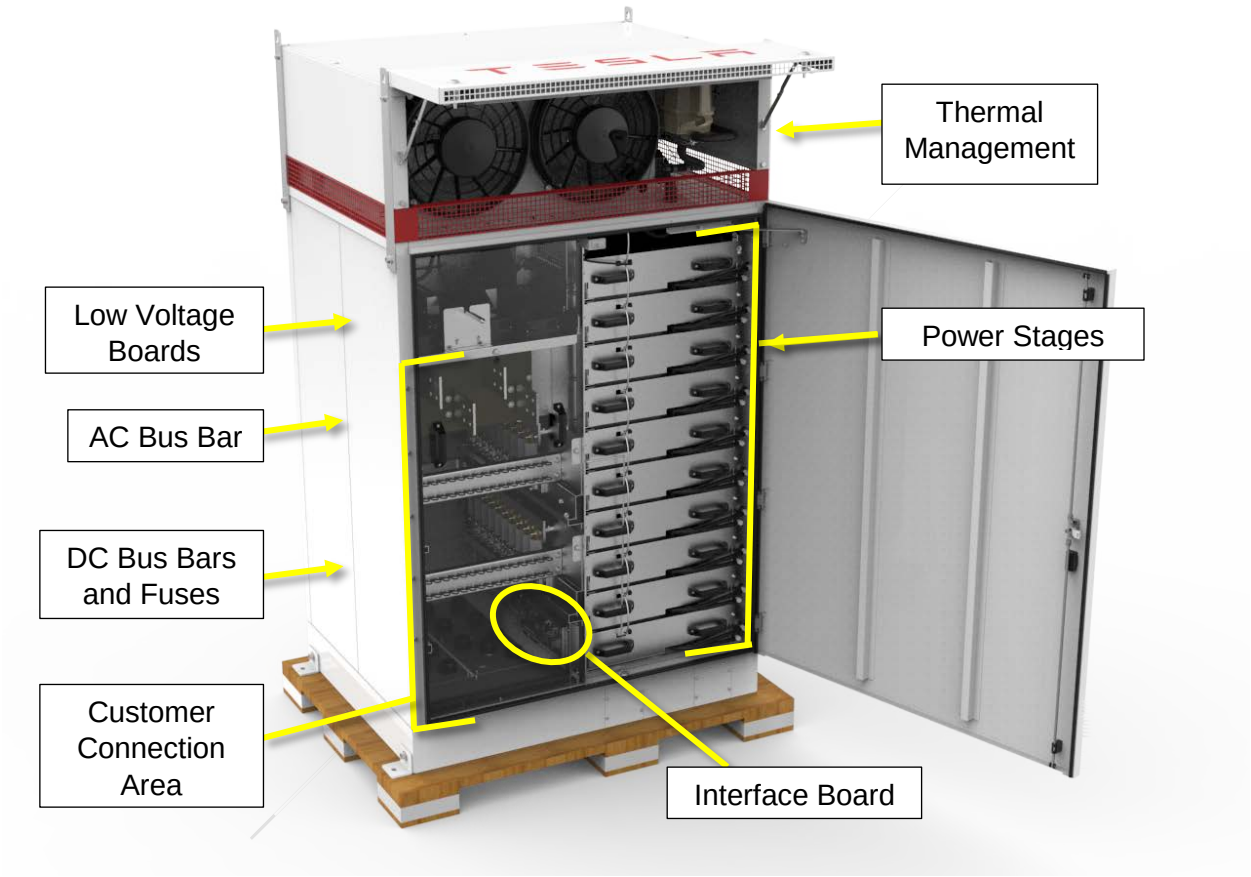

Figure 4: Powerpack Inverter Overview

Low Voltage Section

The upper left part of the main inverter enclosure houses internal low voltage components. These include internal stirring fans and components that manage the thermal system, external I/O low voltage power supplies, and communications.

Power Stage Section

The right side of the inverter enclosure contains up to ten rack-mounted power stages that can be scaled for the needs of the site. Power stages are pre-installed in the inverter before shipment. Each power stage is identical and capable of supplying a maximum AC continuous current of 80A. These modules slide into a rack much like a server rack, with touch-safe high-voltage blind-mate connections on the back of each unit. Coolant connection, LV power, and communications are accessible from the front of the unit.

Thermal Management Section

The thermal management system is housed in the top space of the inverter enclosure. It includes 2 fans, a radiator, and 2 pumps that circulate a 50/50 ethylene glycol/water coolant mix through the system to maintain thermal control. The thermal management system is a fully closed-loop system.

Safety Features

The AC and DC bus bars are covered by a clear shield that must be removed for access. The inverter door also has a DC disconnect switch that is accessible from the front of the unit and can be locked in the open position (Figure 5). The DC disconnect switch ties into the Enable safety circuit that also runs through all Powerpack Units.

Figure 5: Powerpack Inverter DC Disconnect Switch

Powerpack Controller

The Powerpack Inverter communicates with the overall system through the Powerpack Controller (or “Controller” in this manual), which controls the entire energy storage site. The Powerpack Controller hosts the control algorithm that dictates the charge and discharge functions of the Powerpack Units. It is also the single point of interaction with external parties. One Powerpack Controller is required per point of interconnection, and is provided pre-assembled in a NEMA 3R enclosure (Figure 6).

Figure 6: Example Powerpack Controller

The Powerpack Controller communicates to each inverter block over a private TCP network. Each inverter communicates with the Powerpack Controller and commands the Powerpack Units. For larger sites, multiple inverter blocks are connected via Ethernet to a network switch.

NOTE: Refer to Tesla's *Communication Interface Manual* for how to interface with the Tesla Powerpack System.

Tesla Meters

Meters are provided by the contractor. Every site requires a "battery meter" that measures the AC energy output of the battery system (Figure 7). A "site meter" (that measures the net load of the site with the battery system included) is optional. An additional "solar meter" might also be required for sites involving PV installations.

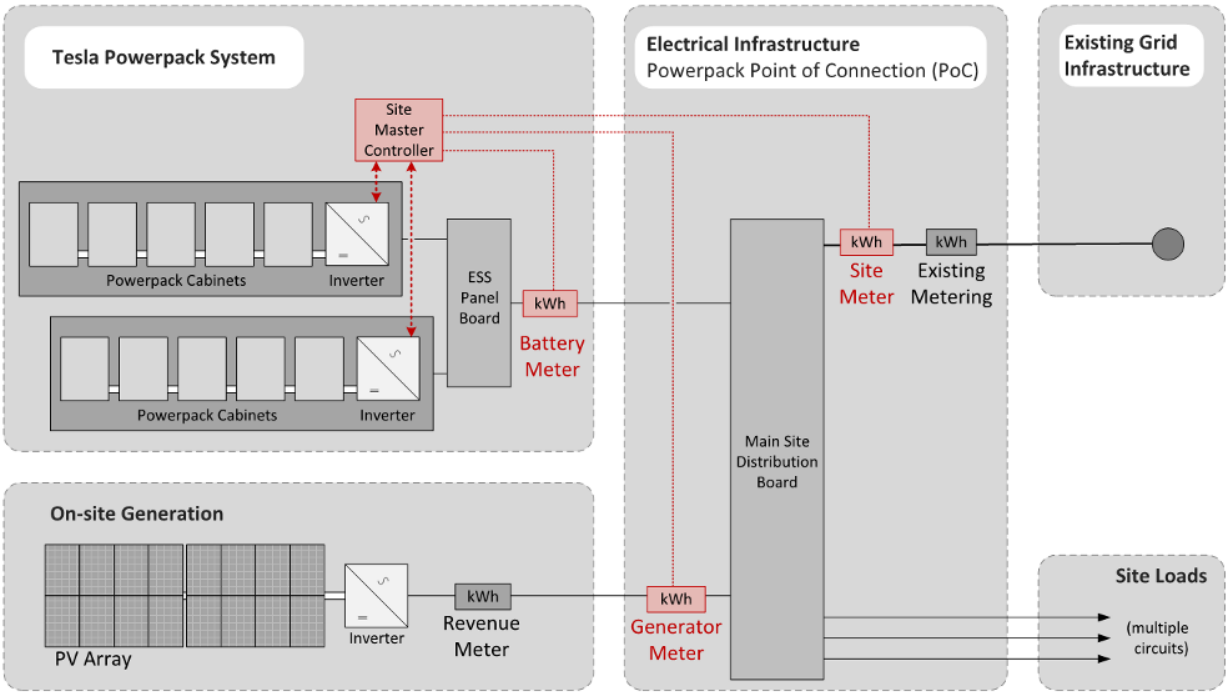

Figure 7: Metering Overview

For a list of currently supported meters, refer to Tesla's *Communication Interface Manual.*

Battery Meter

The Powerpack System requires a meter to measure the AC energy output of the system. The customer can either provide a single aggregated meter for the Powerpack System, or multiple battery meter inputs if the system is segregated.

Site Meter

The site meter measures the site net load with the Powerpack System included. The site meter is typically located adjacent to the utility meter or at the point of common coupling (PCC). The site meter is required to use all features described in the *Communication Interface Manual*, except for the Direct Real Power command.

2. System Description

The basic layout and interconnection of components are shown in Figure 1. At a high level, the DC power and communications from each Powerpack Unit are aggregated in the Powerpack Inverter to provide AC power. See the “Site Requirements” section for layout requirements.

All Tesla-approved inverter block configurations are provided in “Appendix: Approved System Configurations”.

System Specifications

Mechanical Specifications

Equipment	Length	Width	Height	Weight	Mounting
Powerpack Unit	51.5” (1308 mm)	32.4” (822 mm)[1]	86” (2185 mm)[1]	4765 lbs (2160 kg)	Pad
Powerpack Inverter	39.9” (1014 mm)	49.4” (1254 mm)[1]	86.3” (2192 mm)[1]	2650 lbs (1200 kg)[2]	Pad
Powerpack Controller	9” (229 mm)	17.8” (453 mm)	19.6” (499 mm)	30 lbs (14 kg)	Rack

[1] Dimensions do not include inverter removable mounting feet and lifting flanges, which add 136 mm (5.4 in) to the width and 50 mm (2 in) to the height

[2] Maximum weight (weight changes depending on number of installed power stages)

The center of gravity is two-thirds the height of the Powerpack Unit. The center of gravity of the inverter varies based on the power rating configuration. For a max power configuration (10 power stages), the vertical center of gravity is below half of the unit height.

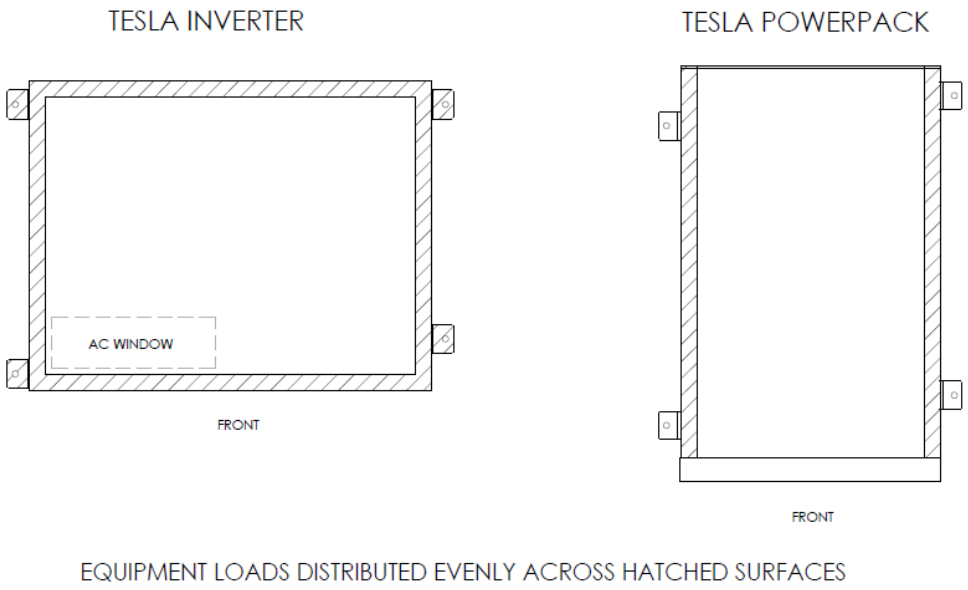

Figure 8: Seismic Loads

Environmental Specifications

Operating Temperature, Outdoor*	-30°C to 50°C
Operating Temperature, Indoor	-30°C to 30°C
Humidity	Up to 100% condensing
Storage **Up to 1 week:** **Up to 1 month:** **Up to 12 months:**	 -30°C to 60°C -30°C to 45°C, <95% RH non-condensing -20°C to 30°C, <95% RH non-condensing, SOE: 25% initial
Maximum Altitude	3000 m (9840 ft) above sea level
Wind	150 mph per ASCE 7-10
Ingress Rating	IP67 (Pod) / IP66 (Powerpack Inverter) NEMA 3R / IP35 (Powerpack Unit) NEMA 3R / IP54 (Powerpack Inverter)
Impact Rating	IK09
Noise	Powerpack Inverter: < 70 dBA at 1 meter Powerpack Unit: < 82.5 dBA at 1 meter
Seismic Rating	High seismic level, 1.0g ZPA, 2% damping per IEEE 693-2005 SDS = 1.56g (z/h=1) and SDS = 2.50g (z/h=0) per ACI 156

**Installation in full sun raises the temperature inside the enclosure above ambient temperature. This temperature rise is not a safety risk, but can impact the performance of the batteries. A canopy to shield the installation from direct sun exposure is permitted, as long as the canopy does not impact the ability to service, remove, or replace the equipment. A canopy design that is less than five feet above the unit must be reviewed and approved by Tesla engineering.*

Power Specifications

The inverter is set to a nominal voltage of 400 VAC or 480 VAC. The specs below are split for each default voltage value:

Grid-Connected (Utility-Interactive) Mode

Default Voltage	**400 VAC**	**480 VAC**
Rated Output Power (for 10 modules)	500 kW	625 kW
Rated Reactive Power (for 10 modules)	500 kVAr	625 kVAr
Overload Capability (10 s max)	600 kVA	750 kVA
AC Voltage (configurable)	380-480 VAC	
Nominal Frequency (configurable)	50 or 60 Hz	
System configuration	4-wire, Wye grounded	
Max Output Current per module	80 A	
Peak Efficiency	98.9%	99%
Full Load Efficiency	98.4%	98.5%
CEC Efficiency	99%	
Total Current Demand Distortion (TDD)	< 3%	
Power Regulation Accuracy	< 2%	
Overvoltage Category	Category III up to 3000 m	

Supplemental Specifications for Grid-Forming (Islanding) Mode

Imbalanced Phase Load Power Output	100%

Nameplate Ratings

Number of Power Stages	**kVA Nameplate at 400V**	**kVA Nameplate at 480V**
1	50	63
2	100	125
4	200	250
5	250	313
8	400	500
10	500	625

The inverter may be de-rated by changing software parameters to meet specific site restrictions and requirements.

3. Product Configurations

Tesla configures two main variables for each inverter, according to system need:

- 1 to 10 power stages
- Four DC fuse variants: 5, 10, 15, or 20 pre-installed DC fuses (per phase), depending on the number of paired Powerpack Units per inverter

NOTE: Inverter configurations are at Tesla's discretion.

Table 1 describes the available inverter configurations, with their corresponding power values.

Table 1: Inverter Configurations

Number of Power Stages	Max Power (kVA) *480 VAC Configuration*	Max Power (kVA) *400 VAC Configuration*	Max Continuous Current (A)
1	62.5	50	80
2	125	100	160
3	187.5	150	240
4	250	200	320
5	312.5	250	400
6	375	300	480
7	437.5	350	560
8	500	400	640
9	562.5	450	720
10	625	500	800