



LIQUID-COOLED POWERTITAN 2.0 BATTERY ENERGY STORAGE SYSTEM

WHITE PAPER

TABLE OF CONTENTS

1. Executive summary.....	01
2. Introduction.....	02
3. Understanding the safety concerns with batteries.....	03
3.1. Overview of BESS quality risks and manufacturing defects.....	03
3.2. CEA's findings on fire safety and risks.....	03
3.3. Market response to BESS fire safety concerns.....	04
4. Liquid-cooled technology overview.....	05
4.1 What is liquid-cooled technology?.....	05
4.2. Advantages over traditional air-cooling lithium-ion technologies.....	05
5. Sungrow's fully liquid-cooled PowerTitan 2.0 BESS.....	06
5.1. Introduction to PowerTitan 2.0 BESS.....	06
5.2 BESS safety features for fire suppression and thermal management.....	08
5.3. Additional key features and innovations.....	11
5.4. Certifications and design standards.....	12
5.5. Quality assurance and factory acceptance testing.....	12
7. Conclusion.....	13

EXECUTIVE SUMMARY

Battery energy storage system (BESS) technologies are propelling us towards a net-zero economy. They're necessary for harnessing the full power of intermittent renewable energy sources without experiencing gaps in power.

However, while generally effective and reliable, some have expressed concerns over the quality and safety of batteries. Leaders in the fossil fuel industry, for example, have been quick to criticize this technology. And because batteries are relatively new, the media and public tend to treat any issues with heightened levels of attention and scrutiny, threatening the deployment of battery technology.

To address these concerns and increase the adoption of BESS technology, companies need to ensure that batteries are as safe, reliable, and powerful as possible.

Sungrow has recently introduced a new, state-of-the art energy storage system: the PowerTitan 2.0 with innovative liquid-cooled technology. The BESS includes the following unique attributes:

- Offers an **easily scalable design** with plug-and-play architecture backed by pre-certified fire safety compliance testing.
- **Maintains consistent temperatures** – increasing performance, safety, reliability, and profitability.
- **Reduces installation time by 80%**, compared to a conventional ESS, requiring only one hour for cabinet installation due to its pre-integrated design.
- Ensures a **Ensures a high ROI by reducing auxiliary power consumption by 40%** (compared to a conventional ESS) – prolonging system life and mitigating unnecessary degradation.
- **Sustains top performance in harsh environments** – including high humidity areas, dusty deserts, or high elevations up to 3000 meters (9843 feet) above sea level.
- Includes **enhanced safety features for fire suppression and thermal management**.

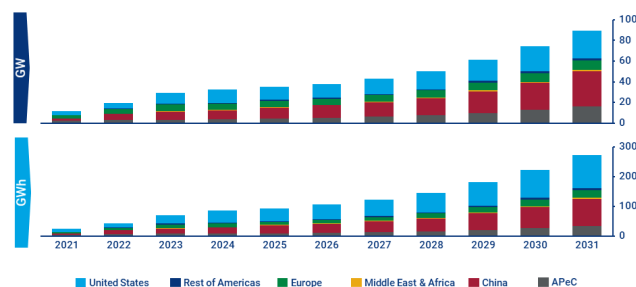
This white paper outlines the promise and criticisms of batteries, and highlights the key features, benefits, and market significance of Sungrow's liquid-cooled PowerTitan 2.0 BESS as an integrated turnkey solution from cell to skid.

INTRODUCTION

Energy storage is essential to the future energy mix, serving as the backbone of the modern grid. The global installed capacity of battery energy storage is expected to hit **500 GW** by 2031, according to research firm Wood Mackenzie.

The global energy storage ten-year market outlook is bright

Annual deployments by region: 2021-2031



Source: Wood Mackenzie

[Click to view chart](#)

The U.S. remains the energy storage market leader – and is expected to install **63 GW** of storage between 2023 and 2027, and exceed **130 GW** by 2030. The U.S. Inflation Reduction Act has further increased projected solar and onshore wind capacity by **40%** and estimated battery capacity by an additional 20 GW.

As the young industry rapidly grows, concerns about quality and safety have emerged – including the possibility of battery fires.

While rare, these issues can occur due to low integration of energy storage systems, inconsistent design standards and quality control, lack of experience in managing energy storage systems throughout the life cycle, and improper understanding and implementation of standards.

Ultimately, thermal runaway and system-level defects can result in costly delays and downtime – and in very unlikely scenarios, potential threats to safety.

Importantly though, batteries are overwhelmingly safe and effective. The California Public Utilities Commission, for example, estimates that only **2%** of grid storage facilities will experience “major safety-related” incidents.

Notably, the natural gas industry causes **thousands** of explosions every year in the United States. But these incidents often go unreported or do not face heavy scrutiny.

Nevertheless, given lingering skepticism about batteries, Sungrow recognizes the importance of providing cutting-edge solutions that meet top performance and safety standards. Sungrow’s PowerTitan 2.0 liquid-cooled BESS marks the next generation of highly integrated, plug-and-play, pre-certified grid-scale energy storage – offering unmatched reliability, efficiency, performance, and safety to invest in batteries with confidence.

UNDERSTANDING THE SAFETY CONCERNS WITH BATTERIES

3.1. OVERVIEW OF BESS QUALITY RISKS AND MANUFACTURING DEFECTS

Over the past decade, battery cells have [expanded](#) their capacity from under 100 Ah to 300+ Ah, transitioned from 12-meter walk-in containers to highly integrated, adaptable cabinets half the size, and incorporated liquid-cooled technology to support larger batteries. This rapid change and high growth rate has introduced new risks across the supply chain, such as manufacturing defects and complex subsystems with additional points of failure, which can lead to uncontrolled [thermal runaway](#) (a chain reaction that can cause fire, or rarely explosions).

As more novice players enter the energy storage industry, there are huge product variations, which can result in various fire hazards. Advanced components like the battery management system (BMS), energy management system (EMS), and power conversion system (PCS) are supplied by different companies – sometimes causing difficult on-site installation, long system commissioning cycles, poor operation adaptability, and frequent on-site operation and maintenance —negatively affecting the levelized cost of energy (LCOE).

3.2. CEA'S FINDINGS ON FIRE SAFETY AND RISKS

Clean Energy Associates (CEA), a leading renewable energy consultancy, conducted over [320](#) quality and safety inspection audits at 52 BESS factories worldwide, spanning 30 GWh of lithium-ion energy storage projects. Their extensive audit – published in February 2024 – revealed that **26% of BESS projects had quality issues related to fire detection and suppression systems and 18% had issues with thermal management systems.**

Nearly half of CEA's quality assurance (QA) findings were related to system-level defects, highlighting overlooked integration problems in the production process. The BESS integration of the cell and module is a highly manual, labor-intensive, and complex process, leading to QA vulnerabilities from lengthy production processes, high-performance sensitivity, and less strict quality control (QC) measures.

Notably, installers screen for and correct these malfunctions during the installation and commissioning process under the nationally recommended safety standard [NFPA 855](#).

But correcting these issues can delay projects for months and reduce profits. That makes it all the more important to prioritize pre-integrated systems and employ rigorous quality control measures throughout the manufacturing process.

3.3. MARKET RESPONSE TO BESS FIRE SAFETY CONCERNS



Batteries are overwhelmingly safe. The problem is: There are still renewable energy naysayers who hope to prevent the utilization of batteries. And as a newer technology, batteries are naturally subject to heightened public scrutiny.

At the [Energy Storage Summit](#) this past March 2024, Aron Branam, VP of development and construction for Arevon Energy, said, “One fire for one battery is a fire for everyone in the industry.” Mike DeSocio, founder and CEO of Luminary Energy, chimed in, saying, “...there has been a lot of trust lost in batteries in New York in the last few years.”

Some communities have imposed [moratoriums](#) on battery permits to assess safety concerns and enhance emergency response planning. Legislative measures, such as California’s [Senate Bill 38](#) signed in October 2023, aim to enforce safety standards and improve emergency response protocols for battery storage facilities.

Safety measures are still evolving in the energy storage industry, with strategies to prevent battery fires differing across each manufacturer as the industry evolves.

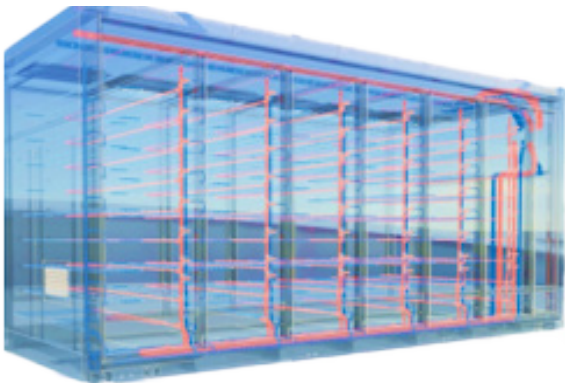
For example, in [Moss Landing](#), California (the [largest](#) operating battery storage facility in the U.S. at 750 MW) the BESS’ fire suppression systems – designed to prevent thermal runaway – were accidentally activated due to [rainwater intrusion](#) (i.e. water ingress), resulting in arcing and short-circuiting from flooding the batteries. Clearly continuous improvement is needed.

“To quell public concern, it’s critical to do everything in our power to reduce the risk of battery malfunctions. Sungrow has done precisely that.

LIQUID-COOLED TECHNOLOGY OVERVIEW

4.1. WHAT IS LIQUID-COOLED TECHNOLOGY?

Liquid-cooled technology is widely utilized in energy storage, electric vehicles, and other energy sectors due to its high energy efficiency ratio and temperature uniformity. The liquid-cooled system uses coolant to move heat from the battery cell enclosure to the ambient environment to lower the overall temperature.



As an ultra-efficient heat exchanger, liquid-cooled technology has a high specific heat capacity and excellent thermal conductivity, able to rapidly transfer more heat from the hotter to colder region and cool down the system more quickly and effectively.

4.2. ADVANTAGES OVER TRADITIONAL AIR-COOLING LITHIUM-ION TECHNOLOGIES

Conventional air-cooled systems use fans to pull in external air, potentially introducing humidity and condensation (i.e., water ingress) into the system, which can lead to short-circuiting and thermal events. Instead, liquid-cooled technology offers improved fire safety, among other benefits, by enabling faster and more efficient cooling.

	Liquid-cooled BESS	Air-cooled BESS
Enhanced efficiency	✓	
Improved thermal performance	✓	
Extended system life	✓	
High energy density	✓	
Low noise	✓	
More reliable operation	✓	
Better scalability	✓	

SUNGROW'S FULLY LIQUID-COOLED POWERTITAN 2.0 BESS

As the world's most [valuable](#) solar company and bankable inverter brand with over 27 years of experience, Sungrow's energy storage systems have exceeded 19 GWh of contracts worldwide. Sungrow has been at the forefront of liquid-cooled technology since 2009, continually innovating and patenting advancements in this field.

“As a system solution supplier and product OEM, as opposed to an integrator, Sungrow is able to achieve a tight integration that is reliably repeatable, high-quality, and system-level safe to adhere to strict third-party guidelines.”

5.1. INTRODUCTION TO POWERTITAN 2.0 BESS

[Sungrow's latest innovation, the PowerTitan 2.0 Battery Energy Storage System \(BESS\)](#), combines liquid-cooled technology with advanced power electronics and grid support features, marking a significant leap forward in BESS solutions.

This plug-and-play BESS uniquely pre-integrates all internal components—including the batteries, string PCSs, BMS, thermal management, and fire suppression systems—within a 20-foot container for easy installation, improved adaptability, and high performance.



Customer reviews highlight flexibility, reliability, safety, and ROI as key priorities. Sungrow's PowerTitan 2.0 not only meets these expectations but also effectively addresses fire safety concerns. Our standout offering includes a **complete turnkey solution, from cell to MV skid, supported by our local in-house service and backed by a 20-year system-level guarantee.** This integrated approach reduces project delays and eliminates the need for on-site system-level certification, setting us apart from competitors, such as DC lock providers, who lack system-level solutions.

The globally liquid-cooled system (encompassing the battery modules and patented PCS) provides top-level performance with a **round-trip efficiency (RTE) up to 92.5%** for 4 hour solutions, with long duration options of 2 to 8 hours available.

Easily scalable

The PowerTitan 2.0 is a **scalable plug-and-play solution backed by pre-certified fire safety compliance testing for fast deployment and reduced risk.**

The BESS also simplifies commissioning efforts and site-level integration. That's largely because it does not have to run conduit between the battery and PCS – lowering conduit by 50%, reducing project footprint, and increasing energy density relevant to traditional solutions.

High-performance

With liquid-cooled technology, the BESS **maintains consistent temperatures within 2.5°C across almost 5,000 battery cells in one container** and eliminates any outlier cells to maximize performance, safety, reliability, and profitability. The system boasts an RTE up to 92.5% for 4 hour solutions, with long duration options of 2 to 8 hours available. This is an enhancement of 2% from the first-generation PowerTitan 1.0, with its Cell to Grid technology (C2G) that simplifies the energy conversion between DC and AC power.

Fast deployment

The all-in-one AC-DC block design streamlines deployment with embedded PCSs, pre-assembled components, MVT, and comprehensive factory testing to reduce installation time by 80% (compared to a conventional ESS), requiring only one hour for cabinet installation.

Additionally, the system comes **pre-certified with AC-level UL 9540**, shortening grid interconnection processes, and adheres to various safety standards. Grid-debugging time is also cut by 50%, lasting only 15 days compared to conventional BESS systems due to necessary pre-installations.

High ROI

Using precise temperature control made possible with liquid-cooled technology, the PowerTitan 2.0 has a high ROI by reducing auxiliary power consumption up to 40% (compared to a conventional ESS), prolonging system life, and mitigating unnecessary degradation. Enhanced temperature balancing enables individual rack control – boosting usable capacity, optimizing system availability, and reducing the discharging barrel effect.

This advanced temperature balancing results in up to a **7% increase in system discharge** (depending on site conditions). In the case of a PCS fault, the system experiences only an 8% loss, as the remaining 11 PCS systems can remain online, unlike traditional centralized BESS setups where a shutdown leads to a 100% loss that can last for days.

Environmental resilience

By eliminating the need for external air to enter the system, the liquid-cooled BESS enhances resilience in harsh environments, such as **high humidity areas, dusty deserts, or high elevations up to 3000 meters above sea level.**

Enhanced safety

The liquid-cooled PowerTitan 2.0 BESS incorporates robust safety features superior to those required in NFPA (National Fire Protection Agency) standards, including separate partitions for power electronics and battery cabinets to prevent thermal runaway, fire-resistant bulkheads lasting up to two hours, and advanced fire protection mechanisms to minimize fire risks.

The battery energy storage system meets global liquid-cooled heat dissipation standards and employs technology to reduce short-circuiting and arcing risks. Also, without introducing foreign particles (such as dust) and humidity into the enclosure, the system mitigates short-circuiting and thermal events for added reliability. As the liquid-cooled system is low noise at or below 75 dBA, the BESS can also operate in noise-restricted environments.

The multi-level architecture of safety measures, such as inter-rack fusing protection, active anomaly detection, and millisecond-level arc detection, enhance overall safety, while multi-stage overcurrent protection and integrated BMS ensure rapid response to potential hazards.

NFPA 855 compliance design options of:
- **NFP** (Deflagration venting) as standard offer
- **NFP** (Explosion prevention system) as an optional choice

NFPA13 compliant Sprinkler and Dry Pipe as an optional choice

SMOKE/TEMPERATURE



NFPA 68 DEFLAGRATION PANEL FOR EXPLOSION RELEASE

NFPA 69 (OPTIONAL) GAS DETECTOR, AIR EXHAUST



FACP



PARTITION DESIGN (BATTERY VS PCS) (BATTERY VS LCU)

MULTIPLE LAYERS SPRINKLER



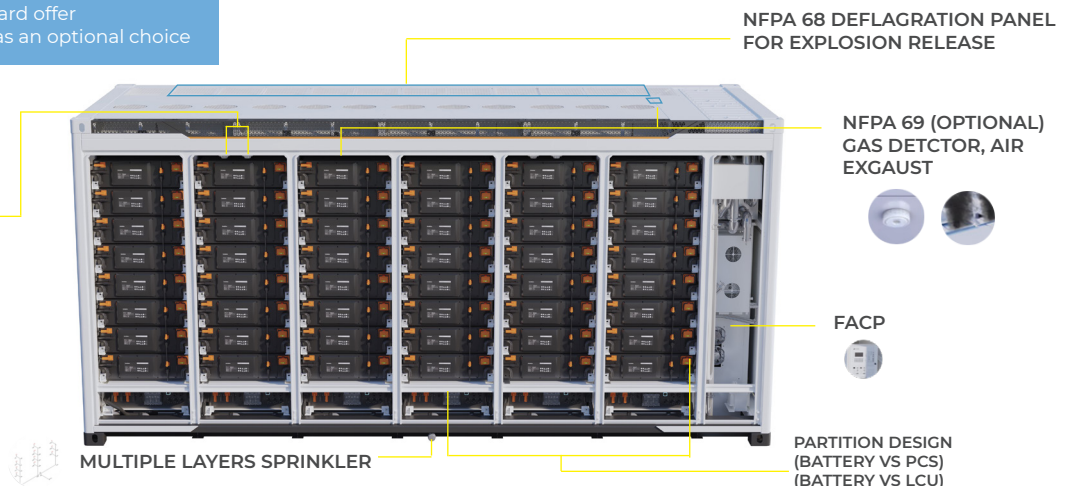
5.2. BESS SAFETY FEATURES FOR FIRE SUPPRESSION AND THERMAL MANAGEMENT

Effective fire suppression and thermal management are crucial for the safety and longevity of energy storage systems. Sungrow prioritizes safety, with a superb track record of zero reported BESS thermal events or explosions.

To uphold Sungrow's strict safety priorities, the PowerTitan 2.0 offers a comprehensive safety design across the cell, electrical, and system levels. From compartmentalized designs to advanced fire suppression systems, the system ensures the highest level of safety and reliability in various operating conditions.

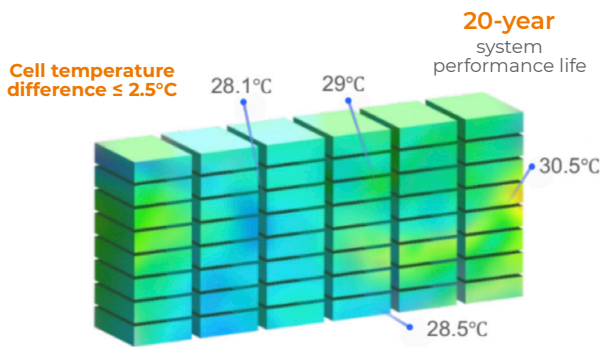
As a liquid-cooled system, as opposed to air-cooled, humidity and condensation are not introduced into the system, removing water ingress – allowing for more control of the system's internal environment conditions and reducing the risk of short-circuiting.

Sungrow's PowerTitan 2.0 liquid-cooled BESS employs various features to address fire safety concerns:



Balanced temperature control:

A patented liquid-cooled heat dissipation scheme and 4D sensing technology maintain a balanced system temperature with a $\leq 2.5^{\circ}\text{C}$ temperature difference across all battery cells – prolonging battery life by two years, reducing degradation, improving auxiliary power efficiency, and enhancing system performance with a 15% increase in discharge capacity over the system's life cycle.



Professional integration:

Integrating BMS and string PCSs improves system compatibility and adaptability for elevated safety and performance – with an RTE up to 92.5% for 4 hour solutions (with long duration options of 2 to 8 hours available) and ease of commissioning.

Overcurrent protection design:

Multi-level fuse protection ensures reliable disconnection to minimize the risk of thermal runaway.

Integrated arc fault detection and arc fault circuit interruption:

Advanced algorithms detect electrical abnormalities, improving system safety by reducing short-circuit current by 75% in 10 microseconds and 100ms-level shutdown for 100% rack-level protection to mitigate thermal events.

Remote monitoring:

In the unlikely event of an electrical fire, the system automatically triggers multiple firefighting measures, preventing battery deterioration and eliminating thermal runaway at the early stage.

Compartmentalized design:

Partition design separates power electronics and battery compartments with fire-resistant walls to prevent fire from spreading for up to two hours, minimizing damage and avoiding fast contagion of thermal runaway.



Integrated AC-DC blocks:

Compared with traditional centralized PCS design, the built-in PCSs and factory-installed interior DC wiring reduces project footprint and safety risks by reducing the risk of short-circuiting and arcing.

System-level fire safety:

To minimize fire risks, reduce flammable gas concentrations, and ensure electrical safety, the system employs overcurrent fast-breaking and arc extinguishing protection, over-temperature protection, NFPA68-compliant deflagration venting, optional integrated sprinklers inside the BESS container, and optional NFPA69-compliant explosion prevention systems.



Manual switch disconnector (MSD):

The technology mitigates the risk of short circuits for safer shipping, maintenance, and lower personal protection equipment, or PPE, classes, translating into faster project deployment with more efficient installation and commissioning.

Rapid arc extinguishing:

Second-level arc extinguishing eliminates potential fire hazards by blocking thermal runaway at the source.

Pre-testing for fire safety compliance:

Various safety tests, including fire simulations and fire testing, ensure compliance above and beyond industry standards.

Inter-rack fusing protection:

The system reduces the incident energy with low arc energy and protects the safety of maintenance personnel with a lower class of required PPE by limiting exposure to high voltages and currents.

Self-sealing coolant loop connectors:

The system's patented plug connectors for liquid cooling have prevented 100% of leaks in over 100,000 industrial installations.

5.3. ADDITIONAL KEY FEATURES AND INNOVATIONS

In addition to fire safety, below are various other key benefits of the liquid-cooled PowerTitan 2.0 BESS:

Multi-level monitoring devices:

Multi-level sensors, from the module to the rack and system level, provide real-time insights into performance and system health to ensure system efficiency, safety, and reliability, with integration into third-party SCADA and control systems. These devices enable proactive fault detection and system optimization – decreasing downtime, maximizing performance, and prolonging the system's life.

Increased capacity:

The high performance DC/AC inverter supports 0% to 100% depth of discharge with – enhancing overall efficiency, adaptability, and revenue with increased usable capacity.

Enhanced energy capacity and efficiency:

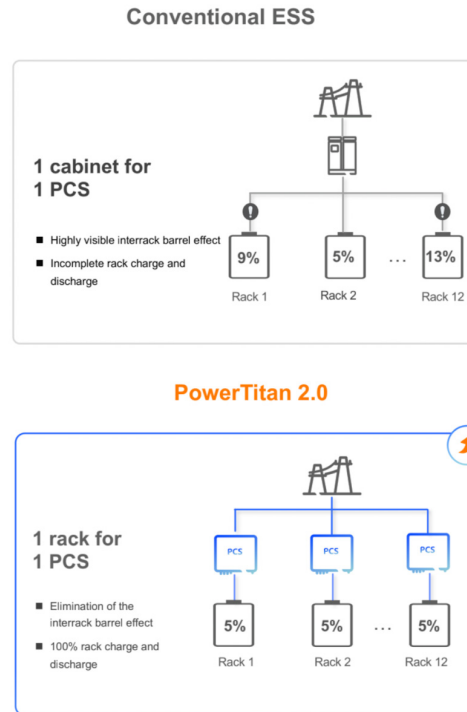
Innovative technologies such as C2G and liquid-cooled thermal management improve energy capacity and efficiency.

Quieter operation:

The system produces less noise than air-cooled systems, at or below 75 dBA, making the BESS suitable for noise-sensitive areas.

Individual rack-level management:

Independent control of charge and discharge in each battery rack increases discharge capacity by up to 7% (depending on site conditions) and improves system flexibility.



Higher energy density:

The system occupies 32% less footprint than a conventional energy storage system with a centralized PCS, improving the LCOE and system energy density with fewer containers, easier construction, and lower balance of plant costs.

Stable operation in weak grids:

Integrated with leading grid following and grid forming control algorithms, the BESS offers advanced grid support functions such as low voltage ride through, frequency and voltage support, black start capability (depending on site conditions), wind-band oscillation suppression, and flexible inertia support.

User-friendly O&M:

Automatic coolant replenishment, auto-calibration state of charge, and refined battery management minimizes O&M costs, enhances system longevity, ensures long-term system reliability, and reduces downtime to boost profitability.

5.4. CERTIFICATIONS AND DESIGN STANDARDS

Sungrow's commitment to quality and safety is reflected in the PowerTitan 2.0's adherence to rigorous certifications and design standards, including NFPA, IEC, and UL standards.

“Pre-certified with UL 9540, the PowerTitan 2.0 eliminates the need for on-site testing – preventing delays, additional costs, and uncertainties for an added layer of confidence.

The PowerTitan 2.0 BESS comes pre-certified with, but not limited to:

- UL 9540 (2023)
- UL 9540A (2019 4th edition)
- UL 1973 (2022)
- UN 38.3 & UN 3536
- UL 1741 SB (PCS) (2019 3rd Edition)
- IEEE 1547:2018 (PCS) (2018)
- CSA C22.2 No.107.1-16 (PCS) (2021 4th Edition)

The battery energy storage system also adheres to the below design standards:

- NEC (2023)
- NFPA 855 (2023)
- NFPA 72 (2022)
- NFPA 68 (2023)
- NFPA 69 (optional configuration)(2024)
- NFPA 13 (optional configuration)(2022)

For more information, refer to the PowerTitan 2.0's datasheet [here](#).

5.5. QUALITY ASSURANCE AND FACTORY ACCEPTANCE TESTING

Sungrow implements a comprehensive QA and QC process management (ISO 9001) to ensure the safety and reliability of the PowerTitan 2.0 energy storage system. This QA and QC includes rigorous procedures such as functional tests conducted in the factory and over 350 quality tests covering cell, pack, rack, PCS, ESS, and energy management strategy testing.

Additionally, Sungrow's state-of-the-art testing facility includes hardware-in-the-loop setups, an in-house lab, a temperature room, a noise room, and a 5 MW grid simulator. **Large-scale fire simulations exceeding UL 9540A standards are performed alongside IP55 liquid-cooled design testing to verify the PowerTitan 2.0 container's system safety under various conditions.** Factory acceptance testing further enhances developer and investor confidence, minimizing commissioning delays.



“By the end of December 2023, Sungrow’s PowerTitan series had secured 19 GWh of global contracts, attributed to its exceptional security features and advanced efficiency.

7. CONCLUSION

Customer feedback consistently points to flexibility, reliability, safety, and return on investment as the most critical factors when choosing a BESS solution. Sungrow’s liquid-cooled PowerTitan 2.0 BESS excels in these areas, while also effectively addressing fire safety concerns.

What truly sets us apart is our Turnkey Solution Value. From cell to MV skid, we provide a complete, end-to-end solution, supported by a local in-house service team and backed by a 20-year system-level guarantee. This integrated approach not only reduces the risk of project delays but also eliminates the need for on-site system-level certification, enabling faster and smoother deployment.

As the energy storage industry continues to evolve, Sungrow remains at the forefront of innovation, delivering system-level solutions that meet the highest standards of quality, safety, and performance. To learn more about how our liquid-cooled PowerTitan 2.0 BESS can drive the success of your next utility-scale project, [reach out to our customer service specialists today.](#)

ABOUT SUNGROW

Sungrow, a global leader in renewable energy technology, has pioneered sustainable power solutions for over 27 years. As of June 2024, Sungrow has installed 605 GW of power electronic converters worldwide. The Company is recognized as the world's No. 1 on PV inverter shipments (S&P Global Commodity Insights) and the most bankable Asian energy storage company (BloombergNEF). Its innovations power clean energy projects in over 170 countries, supported by a network of 490 service outlets guaranteeing excellent customer experience. At Sungrow, we're committed to bridging to a sustainable future through cutting-edge technology and unparalleled service. For more information about Sungrow, visit: www.sungrowpower.com.



SUNGROW

Clean power for all



SUNGROW USA CORPORATION
3200 Park Center Drive, Suite 850,
Costa Mesa, CA 92626

www.sungrowpower.com