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Leading Innovation in ESS Arc Safety

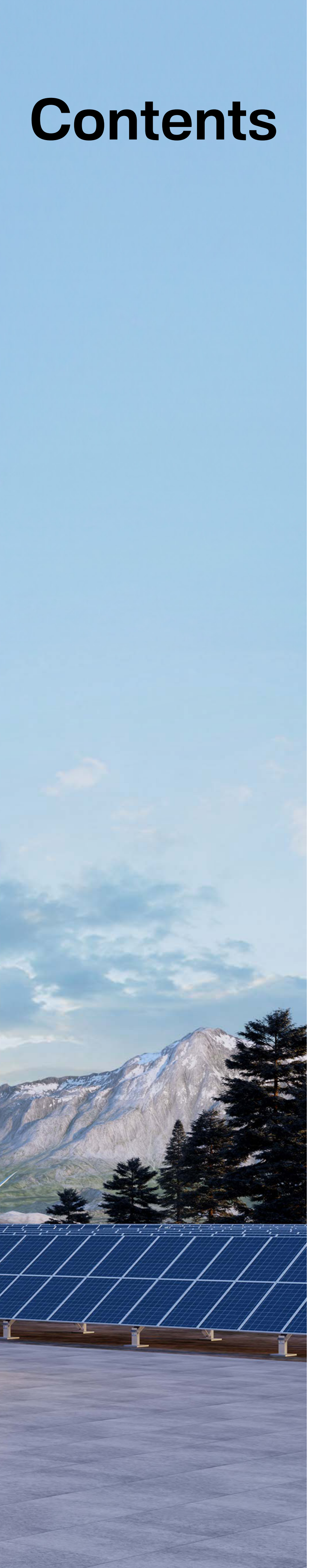
ESS ArcDefender Technology White Paper

Preface

With the accelerated transformation of the global energy structure, energy storage has become a key supporting technology for the large-scale development of renewable energy. In various scenarios such as large-scale renewable energy generation, industrial and commercial energy, and power systems, the application of energy storage systems (ESS) has become an important means to enhance renewable energy consumption, balance energy supply and demand, and ensure the stability of power supply. According to BloombergNEF, the global annual installed capacity of ESS is projected to reach 136.4 GW/445.2 GWh by 2030.

However, the safety of ESS is crucial for sustainable and scalable industry development, especially on the DC side. With the release of high-capacity and long-duration ESS, the current and voltage on the DC side continue to increase. This, along with the rise in the number of batteries and electrical connections, leads to a significant increase in the risk of DC arcing faults. It is noted that the industry has not yet established effective solutions for DC arcing safety challenges for ESS, which exposes personal, equipment, and asset safety to risks, and thus limits the broader application and development of ESS technology.

To enhance industry-wide understanding and address arc safety issues in ESS, SUNGROW, in collaboration with China General Certification Center (CGC) and TUV Rheinland, has released the ESS ArcDefender™ Technology White Paper. This white paper aims to be a valuable reference for the industry, to guide the establishment of standards, stimulate industry collaboration, and collectively promote the safety and efficiency of technology development.



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Prospects and Concerns of ESS Development

1.1 Rapid Global Growth in ESS

As the global energy industry strives to achieve carbon neutrality goals, there is a rapid transition towards clean and low-carbon sources, driving the accelerated growth of the ESS sector. According to BloombergNEF,[①] global ESS capacity has witnessed a significant increase since 2020, with a remarkable addition of 95.8 GWh in 2023 and a compound annual growth rate (CAGR) of approximately 70% during that period. BNEF forecasts that by 2030, the global ESS market will witness an annual addition of 136.4 GW/445.2 GWh in installed capacity.

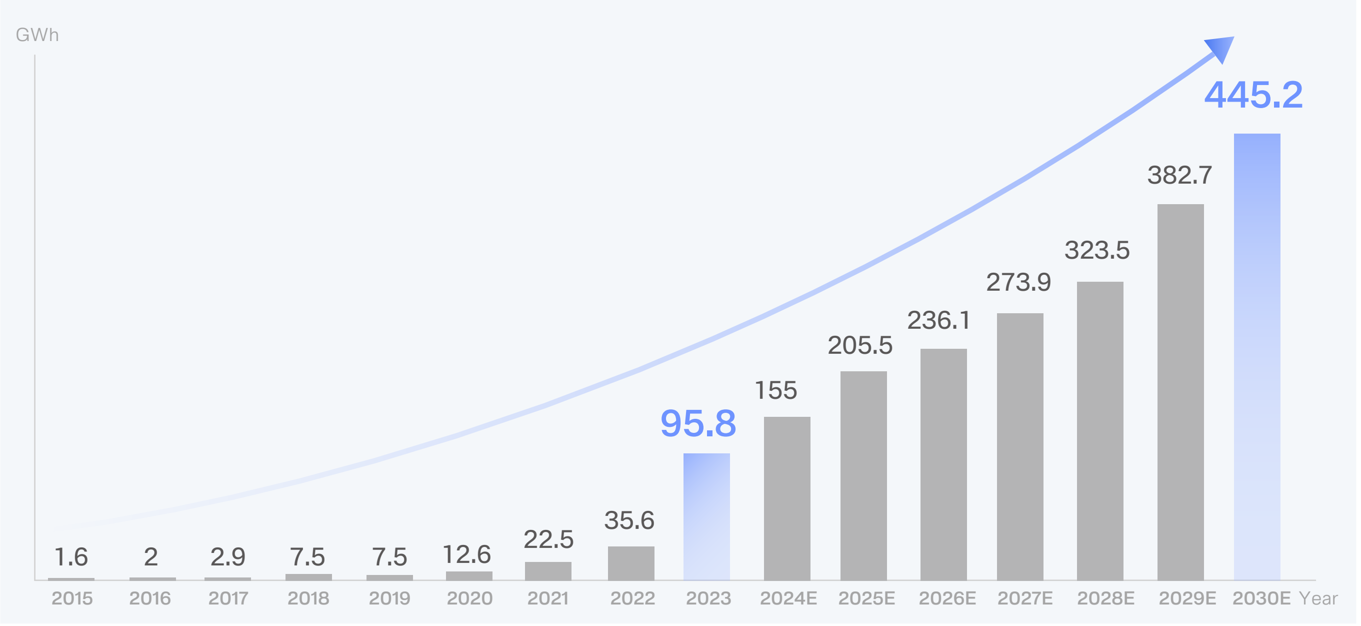


Figure 1 Global regional ESS installation statistics and forecast

The demand for ESS is rising, leading to a surge in participants in the ESS sector. However, intense competition and frequent price wars are common. Moreover, the industry standards are not yet fully developed, resulting in numerous challenges in ensuring the safety of ESS.

1.2 Occurrence of Safety Accidents in ESS

According to publicly available industry information, there have been about 100 ESS accidents worldwide between 2017 and 2023, around 59 of them being fire-related. For example, in May 2022, a large-scale BESS project in Country A experienced an arcing fire accident due to insulation failure caused by liquid leakage. Similarly, In October of the same year, a fire occurred in the ESS of a major data center in Country B, causing disruptions in finance, transportation, and the Internet within the country. As a result, associated companies experienced a decline in stock prices. These incidents show that ESS safety accidents still happen, with fires posing the greatest risks to personal safety, asset security, and society.

① Data cited from Bloomberg NEF -<1H 2024 Energy Storage Market Outlook>, April 25, 2024

Figure 2 Media reports on a fire accident in country A[②]

Industry experts[③] have pointed out that the causes of ESS safety accidents include factors such as unreasonable system design, non-standard implementation processes, defects in battery components, and insufficient supporting measures. According to the analysis of accident cases and industry reports, non-standard implementation processes leading to short circuits and arcing faults are the two main direct causes of fires in ES power plants.

Considering future technological development and product evolution trends, application scenarios such as large-capacity and long-duration ESS are becoming more complex. The continuous rise in DC current and voltage, along with the increasing of batteries and electrical connection points, will exacerbate the risk of DC side arcing faults.

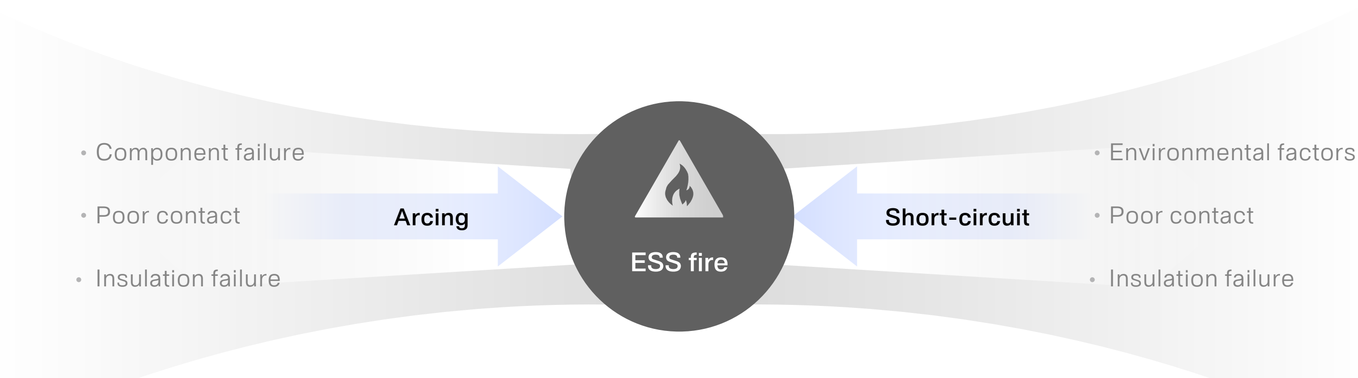


Figure 3 Analysis of causes of ESS fire accident

② The accident analysis information comes from the Energy Storage News website, Andy Colthorpe, 2022-05-11, https://www.energy-storage.news/investigation-confirms-cause-of-fire-at-teslas-victorian-big-battery-in-australia/

The accident pictures are from The Guardian News website,https://www.theguardian.com/australia-news/2021/aug/02/tesla-big-battery-fire-in-victoria-burns-into-day-three#img-1

③ Zhou Xichao, Wang Nan, Xu Jieming, Zhao Mengxin, Zhang Chenguang, Research status of management technology and safety protection technology for lithium iron phosphate batteries [J] Thermal power generation, 2021,50 (06): 14

1.3 Urgent Attention Needed for DC Arcing

1. ESS arcing

Arcing is a continuous discharge phenomenon that occurs when a charged conductor is close to another conductor (or ground), causing the voltage between them to break through the surrounding gas and ionize it. In ESS, arcing can be caused by poor contact at connection points, aging or damage to insulation materials, sudden circuit disconnection, and other factors.

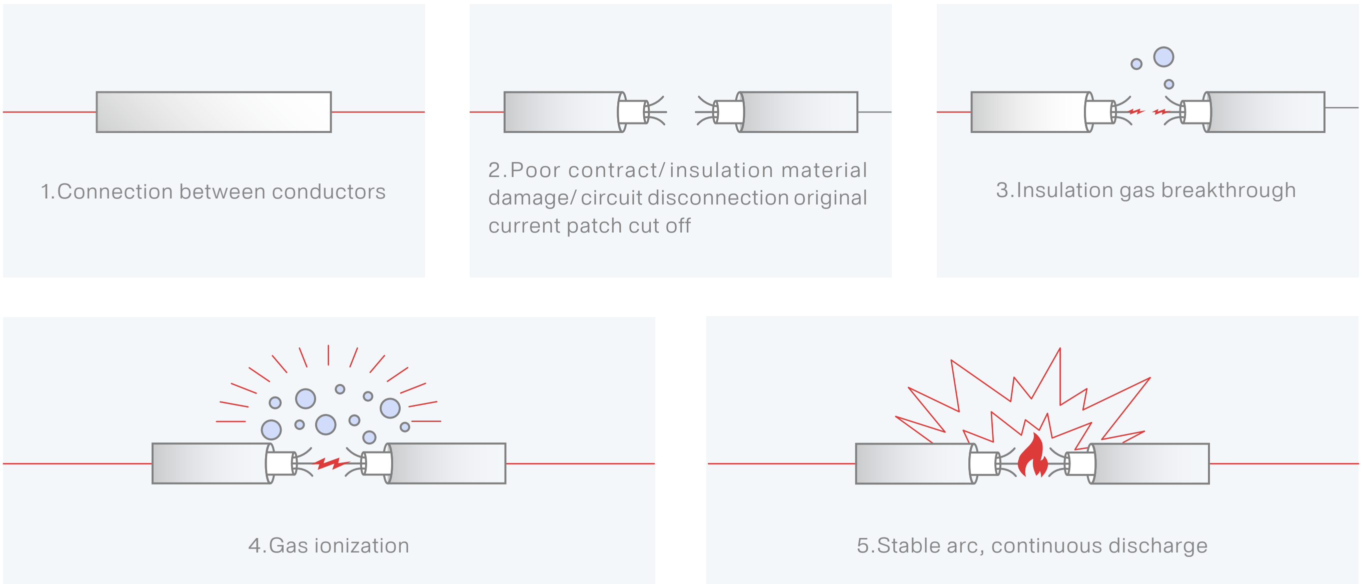


Figure 4 Arc generation process

- ### AC side arcing and DC side arcing

Arcing occurs in both AC and DC power systems. In AC systems, arcs are influenced by the periodic changes in current and intensity. The arc naturally extinguishes at the current zero-crossing point and reignites at the current peak, creating intermittent, pulsed arcs with lower fire risk. Conversely, in DC systems, the stable current and intensity make the arc continuous and difficult to extinguish, resulting in a higher risk of fire.

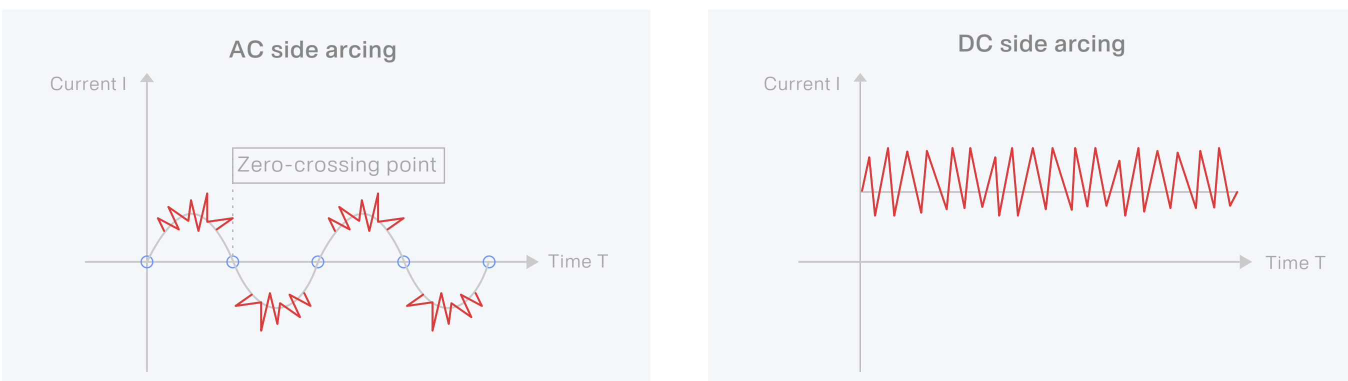


Figure 5 Differences in arcing characteristics between DC and AC sides

• Series arcing and parallel arcing

Based on the circuit connection and arc location, ESS arc can be classified into series arcs and parallel arcs (with ground arc being a special type of parallel arc). Series arcs typically occur within a single charged conductor. Due to the short distance and large number of conductors, series arcing occur frequently. However, the signals from series arcs are weak and can be easily covered by noise so the detection is difficult. If not addressed promptly, they can lead to fires. As for the parallel arcing, it usually occur between different live conductors. Due to the long distance and complex connections between conductors, they occurrence frequency is low. Currently, protection measurements such as fuses and circuit breakers can effectively mitigate the impact of parallel arcs.

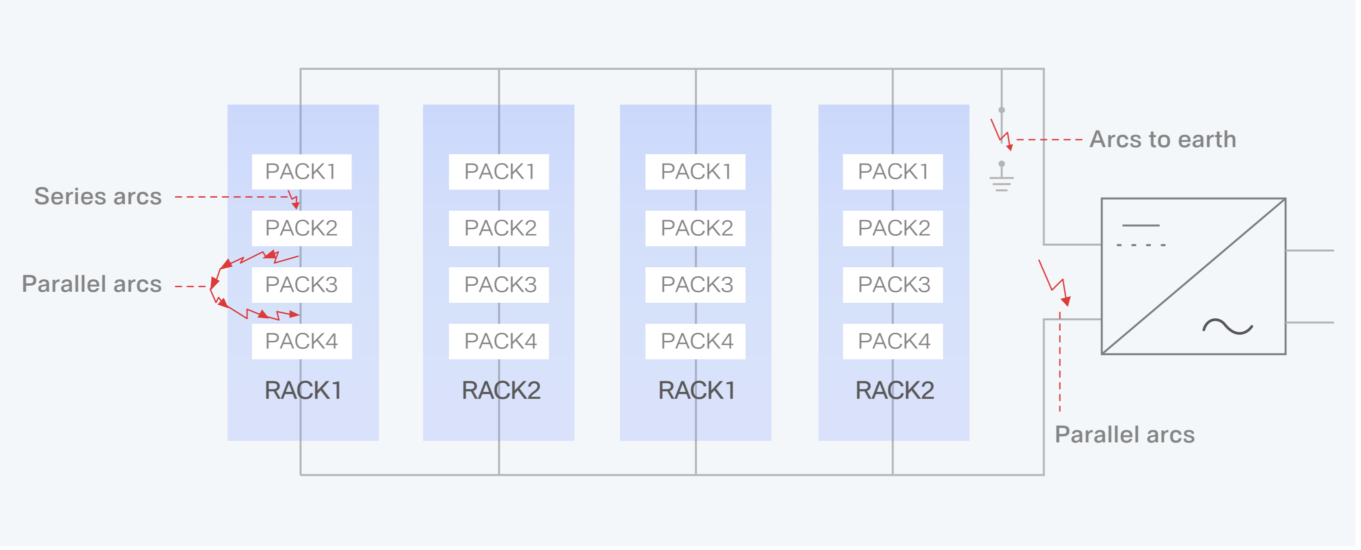


Figure 6: Series and parallel arc positions in ESS

Currently, the risk of DC arcing has attracted widespread attention in the industry. Some national and regional ESS safety standards, such as GB/T42288-2022-5.2.1, IEC62933-5-2, and IEC62485-2, address the risk of DC arcing but have not yet to provide clear requirements and regulations. Due to the high risk of fire, frequent occurrence, and lack of effective countermeasures for series DC arcing, this white paper focuses on discussing the risks and solutions for series DC arcing in ESS. Additionally, we will collaborate with authoritative certification institutions to develop relevant standards.

2. Characteristics and hazards of ESS DC arcing

• The characteristics of ESS DC arcing

High Voltage and Large Current: To meet the requirements for high energy density storage and rapid dynamic response, ESS typically use designs with higher voltage and current. However, this system design does not only increases the probability of arc triggering, but also makes the arc stable, and difficult to extinguish because of the stability of DC current.

Multiple Connection Points: The DC circuits in ESS contain tens of thousands of connection points. These connection points may become a potential arcing fault points due to looseness and other reasons, increasing the risk of arcing. For example, in a 5MWh ESS (see Figure 7), the DC side has over 11,016 connection points (12 battery clusters, 918 connection points per cluster), while the AC side has only 216 connection points (12 PCS, each with 18 connection points). The number of DC connection points is more than 50 times that of the AC side, resulting in a significantly higher risk of DC arc faults.

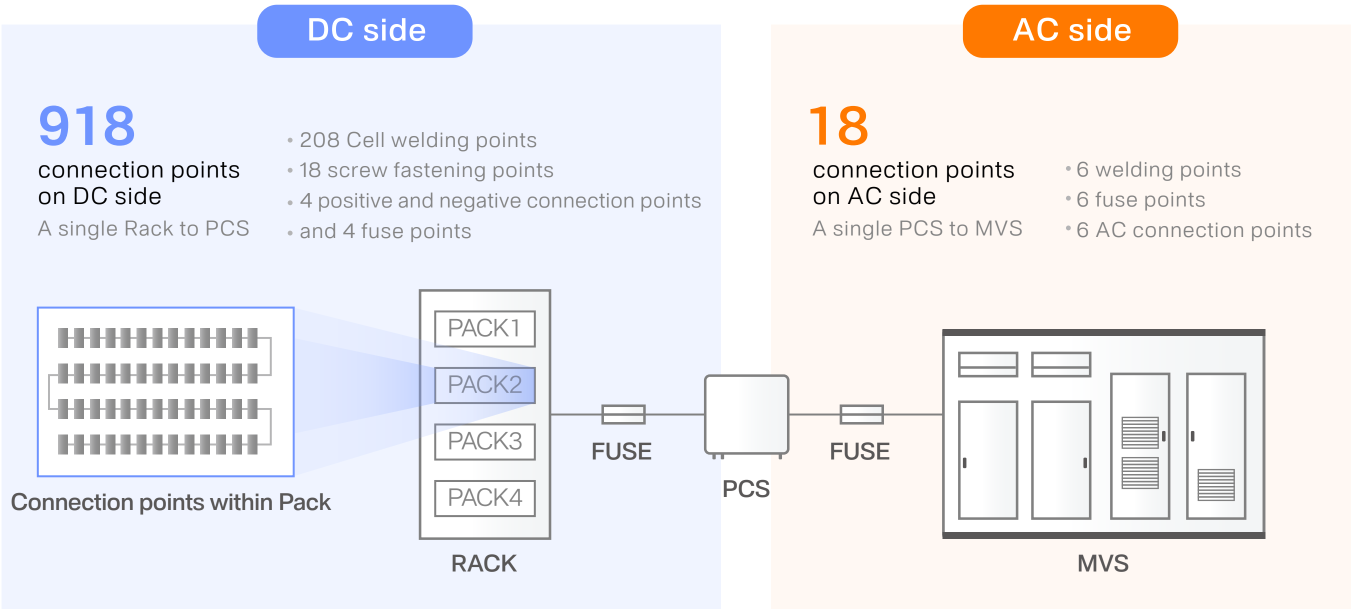


Figure 7 Connection points of single-rack batteries on the DC side and the AC side ④

• The hazards of DC arcing in ESS

As it is operated with high voltage and large current, ESS release a massive amount of energy when DC arcing occurs. The arc core temperature can reach 3000 to 20000°C in air medium. This high temperature can be rapidly transferred to the interior of the cells, which potentially causes thermal runaway and the release of flammable gases, leading to fires and explosions. This poses a severe threat to personnel, equipment, and assets.

Personnel injury: High temperature heat waves, toxic gases, and splashes generated by fires and explosions threaten the health and safety of surrounding workers.

Equipment damage: In addition to generating high temperature, arcing can cause the abnormality of voltage and current, which can damage batteries and other electrical equipment, affecting the efficiency and lifespan of the power station. In severe cases, the operational costs may be increased since a large amount of damaged equipment needs to be replaced.

Impact on the grid: For the ESS connected to the grid, arc faults can cause a sudden drop in output power, negatively impacting the grid stability and power supply reliability, especially during peak demand periods.

Economic Compensation: Equipment damage, production interruptions, and grid instability caused by arc faults result in additional economic burdens for post-incident repairs, recovery, and legal compensation.

In summary, ESS is a crucial component of the global energy transition and has a broad application prospect. However, due to the characteristics of high voltage, large current, and multiple connection points on the DC side, they are more prone to arcing events. Once arcing occurs, it can quickly lead to thermal runaway, releasing a large amount of heat energy and posing a serious threat to personnel safety, assets, and equipment. Therefore, in the risk management of ESS, it is essential to prevent fires caused by DC arcs to ensure safe system operation.

④ Calculate according to the 416s 12p energy storage system

02

ESS DC Arc Technology: Principles and Challenges

2.1 Technical Principles

To better analyze the process of arcing, we can approximate the arc as an equivalent model of a variable impedance in series with a voltage source. The arc can be seen as a voltage source, where the potential difference drives the current through the arc path. The longer the arc path, the higher the voltage and current required to maintain the arc.

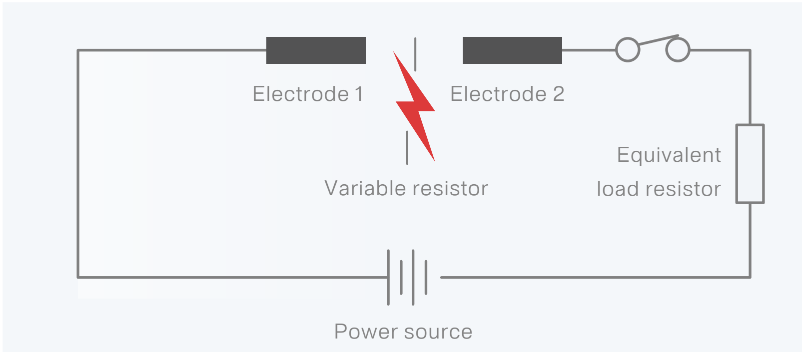


Figure 8: Model of variable impedance in series with a voltage source

When a DC arc fault occurs, the instability of the arc causes irregular and severe fluctuations in current over time and amplitude, which are significantly different from the normal operating current characteristics. The industry typically detects arc faults by monitoring changes in the current spectrum. Once a spectral anomaly corresponding to an arc fault is detected, the system will issue an alert and disconnect the circuit to prevent the danger from escalating.

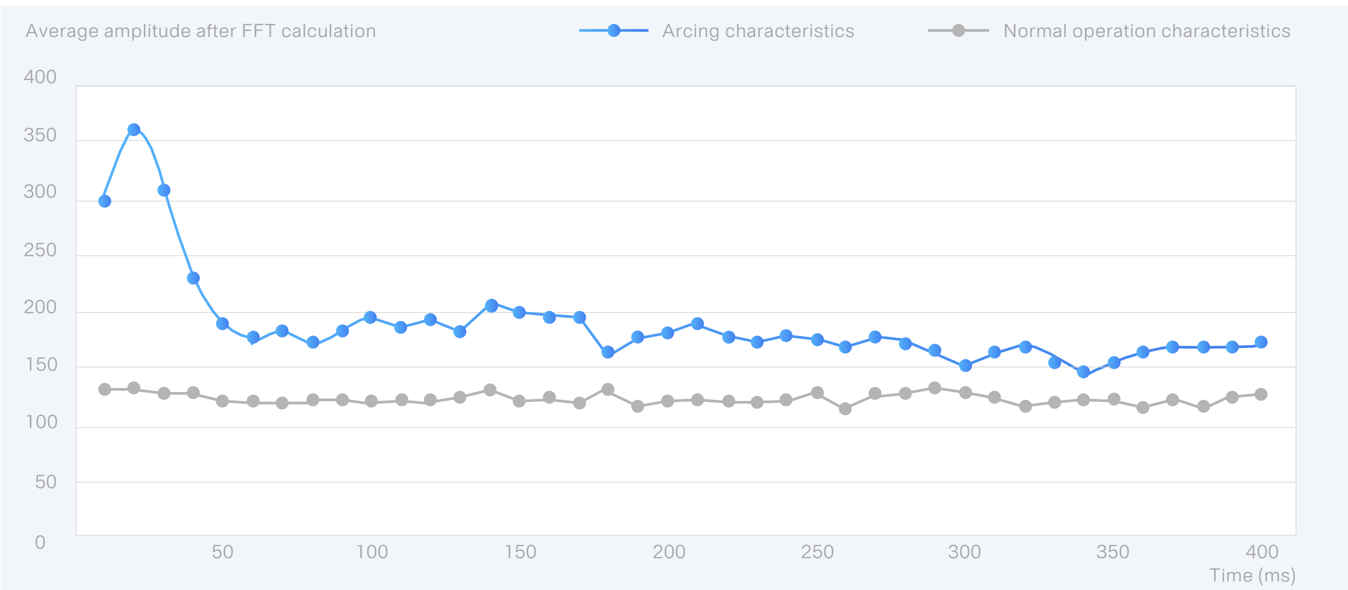


Figure 9 Changes in the characteristic values of arcing

2.2 Technical Development and Application Challenges

Currently, research on DC arc faults in photovoltaic (PV) systems has reached a relatively mature stage. However, research in the area of DC arcing in ESS is still in its early stage, especially in the extraction of arcing characteristics. Some ESS manufacturers utilize physical properties such as arc light, heat, noise, and electromagnetic radiation phenomena to identify arc faults. Nevertheless, these methods have a limited detection range and are not suitable for enclosed battery compartments.

The main reason why it is difficult to overcome the DC arcing, is the complexity of ESS. Core components in traditional ESS, including batteries, power conversion systems (PCS), and battery management systems (BMS), usually come from different manufacturers. The lack of integrated design directly affects the consistency of overall system control logic and data transmission efficiency, thereby impeding the accuracy and speed of arc detection and interruption. Furthermore, considering the characteristics of DC arcs in ESS, the principles of arc detection and interruption, and the current level of technology, the development of arc detection and interruption technology faces the following challenges.

1. High noise interference and inaccurate arc recognition

In the PV field, a relatively mature arc detection technology involves several key steps: First, high-performance current sensors are used to capture time-domain waveform signals of the current. Next, the Fast Fourier Transform (FFT) method is used to extract, analyze, and process these signals in the frequency domain. Finally, the feature modal algorithm and machine learning are used to achieve accurate judgement of the arcing fault.

Figure 10 Schematic diagram of photovoltaic arc detection

However, when applying this technology to ESS, several challenges such as poor noise adaptability and unclear frequency domain characteristics are raised. Specifically, the maximum DC current for PV arc detection is typically 20-30A, while for ESS arc detection it exceeds 200A. Moreover, the increase of DC current leads to a proportional increase of noise in the frequency domain characteristics. As shown in Figure 11, in the 30-100kHz frequency range, PV arc frequency domain characteristics are very obvious, but while that of ESS are completely covered by noise, making it difficult to detect spectral changes.

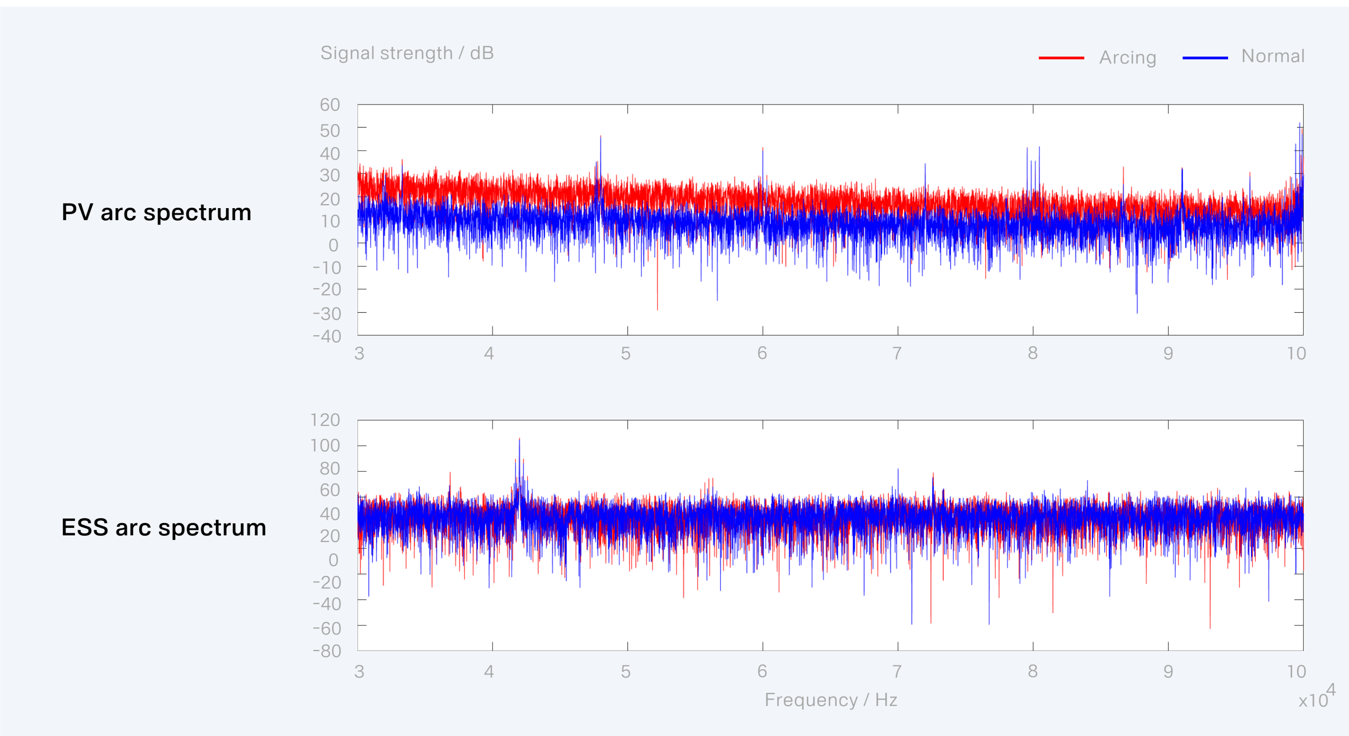


Figure 11 Comparison of PV- ESS arc spectrum

2. High arc energy, leaving less time for arc extinguishing

In accordance with the CGC/GF208:2022 specification, the DC arc shutoff time for PV systems is limited to no more than 2.5 seconds. However, PV arc extinguishing technology is not capable to address the arc extinguishing challenges in ESS.

Due to the high operating current and voltage on the DC side of ESS, when an arc fault occurs, it generates more energy and heat, and is prone to rapidly triggering thermal runaway. Based on the arc energy calculation formula, within the same arc duration (t2-t1), the energy of an arc in an ESS Q_{arc} is approximately 20 times higher than that of a PV system. This significantly increases the risk of thermal runaway and intensifies the urgency of arc extinguishing.

Parameters/Scenarios	PV system	ESS
I_{arc} DC side working current	20~30A	≥200A
U_{arc} Voltage at both ends of arc drawing	10V	≥20V

$$Q_{arc} = \int_{t_1}^{t_2} U_{arc} \cdot I_{arc} \cdot d_t$$

Q_{arc} : Arc energy (Unit: J)

t_1 : The moment when the arc voltage is 10V (Unit: s)

U_{arc} : Arc voltage (Unit: V)

t_2 : The moment the arc current is less than 250mA (Unit: s)

I_{arc} : Arc current (Unit: A)

Therefore, the arc extinguishing time in ESS faces stricter requirements. It must have a faster response capability and ensure there are no false alarms or missed detections to minimize the damage caused by arcing. Due to the lack of relevant standards, the industry has not yet set a clear specification for safe arc extinguishing time in ESS.

Additionally, the complex application scenarios and environmental factors of ESS increase the probability and complexity of arcing, demanding higher accuracy and response capability for arc detection. For example, in high humidity and salt mist environments, moisture and salt can accelerate insulation corrosion, increasing the risk of arc faults. Furthermore, in off-grid scenarios, the absence of grid voltage support and various load characteristics result in more complex current frequency domain characteristics, making the detection and identification of ESS arc faults more challenging.

03

SUNGROW ESS ArcDefender™ Technology Solution

In response to the above challenges, SUNGROW fully uses its profound integration advantages in electrochemistry, power electronics, and grid support technologies. With extensive experience in the development of digital ESS, SUNGROW introduces a comprehensive solution that combines ESS arc risk prediction and suppression functions.
As the core equipment for power conversion in ESS, the PCS connects the battery and the grid, making it crucial for DC side safety management and overall system reliability. To better realize functions such as current detection, analysis, and waveform sealing determination, the arc detection and control unit can be integrated into the PCS. Therefore, this white paper focuses on the PCS integration solution as an example for discussion.

3.1 Technical Proposal

SUNGROW ESS ArcDefender™ DC Arcing Technology is an innovative integrated solution based on PCS to address the safety risks caused by DC arcing in ESS. It can identify and control DC arcing in real-time by applying core technologies, including TMR⑤ high-precision sensing, risk data monitoring, and dynamic arc identification algorithms. This comprehensive solution ensures arc prevention, accurate arc identification, and rapid arc extinguishing, thereby ensuring the safe and stable operation of ESS in high voltage and large current environments. It helps investors mitigate risks and enhance operational returns throughout the entire lifecycle.

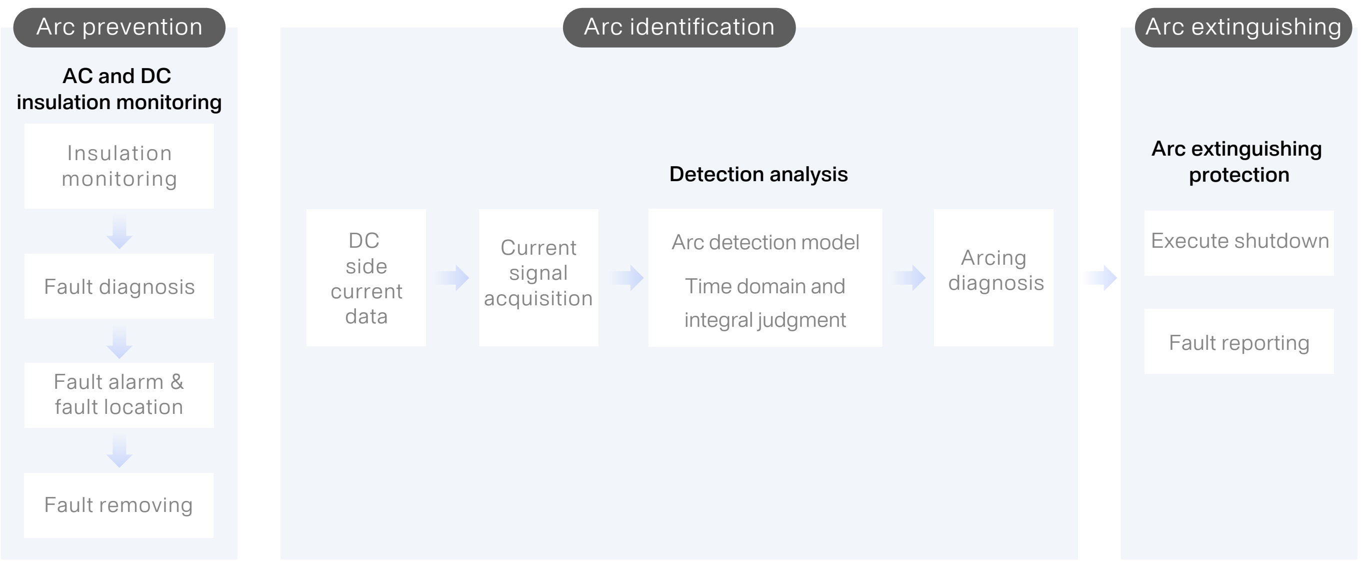


Figure 12 ESS ArcDefender™ technology solution

1. Comprehensive arc prevention

Prevention comes before treatment. To minimize or eliminate arcing incidents, SUNGROW optimizes electrical design to reduce the possibility of arcing at its source. Besides, real-time monitoring of electrical hazards ensures that, potential issues are promptly detected and addressed.

⑤ The TMR tunnel reluctance current sensor is a type of sensor that utilizes Tunneling Magnetoresistance（TMR）.

- ### Electrical structure optimization

In the latest PowerTitan 2.0 large-scale ESS and PowerStack 200CS C&I ESS products, SUNGROW promotes the application of AC storage technology across all scenarios, ensuring the safety of the ESS. To address arc safety, AC storage integrates built-in PCS design, keeping DC confined inside the cabinet, using short DC cables, minimizing arcing in multiple branches, and finishing DC-side wiring within the factory. These enhancements significantly reduce the risk of arcing caused by connection or insulation failures.

- ### Real-time monitoring of electrical hazards

Arcing caused by insulation failure is common in ESS, especially in high humidity and high salt environments. SUNGROW's PCS insulation diagnosis function can detect DC-side impedance before startup and monitors AC-side impedance 24/7. Impedance data is uploaded and analyzed in real-time, providing early warnings of insulation faults and significantly improving system safety and reliability.

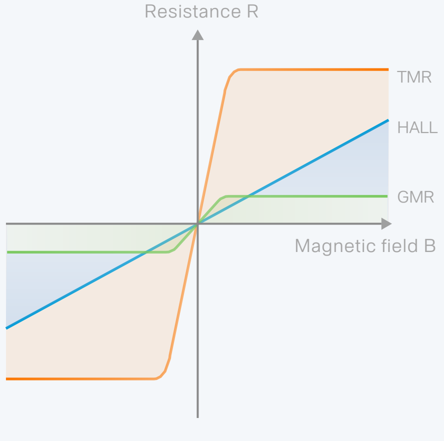
2. Accurate arc identification

The DC side of ESS is characterized by high voltage, large current, and multiple connection points. In order to prevent fire safety incidents, it is essential to achieve accurate detection and determination to ensure that there is no omission and no false alarms, from signal sensing to processing.

- ### Arc signal collect

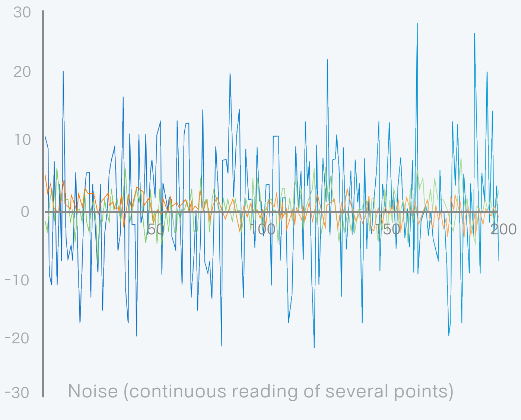
By integrating TMR current sensors and high-performance analogue filters, the PCS can collect DC current data with high sensitivity and high signal-to-noise ratio. This allows for amplification and analysis of arc signal characteristics, enabling high-precision monitoring of weak current signals.

***Comparison of sensing effects**



TMR has the highest rate of magnetic resistance change and higher sensitivity, enabling it to detect small changes in magnetic fields.

***Comparison of signal-to-noise ratio effects**



TMR has the lowest noise amplitude and the highest signal-to-noise ratio for effective signal output.

■ TMR: tunneling magnetoresistance current detection ■ Hall: hall effect sensor ■ GMR: giant magnetoresistance sensor

Figure 13 Performance comparison between TMR and mainstream sensing technologies

- ## Arc signal identification

SUNGROW has developed a dynamic algorithm for PCS arc identification, using a "short-time time & frequency-domain trigger+variable gain integration decision algorithm" instead of the traditional "long-time frequency-domain feature extraction, comparison, and integration decision algorithm." This significantly improves the speed and accuracy of arc fault identification. Additionally, relying on high-performance processors and AI deep learning technology, it enhances the generalization ability of the arc identification model, allowing it actively adapt to various environmental noise changes and effectively prevent false alarms and omissions.

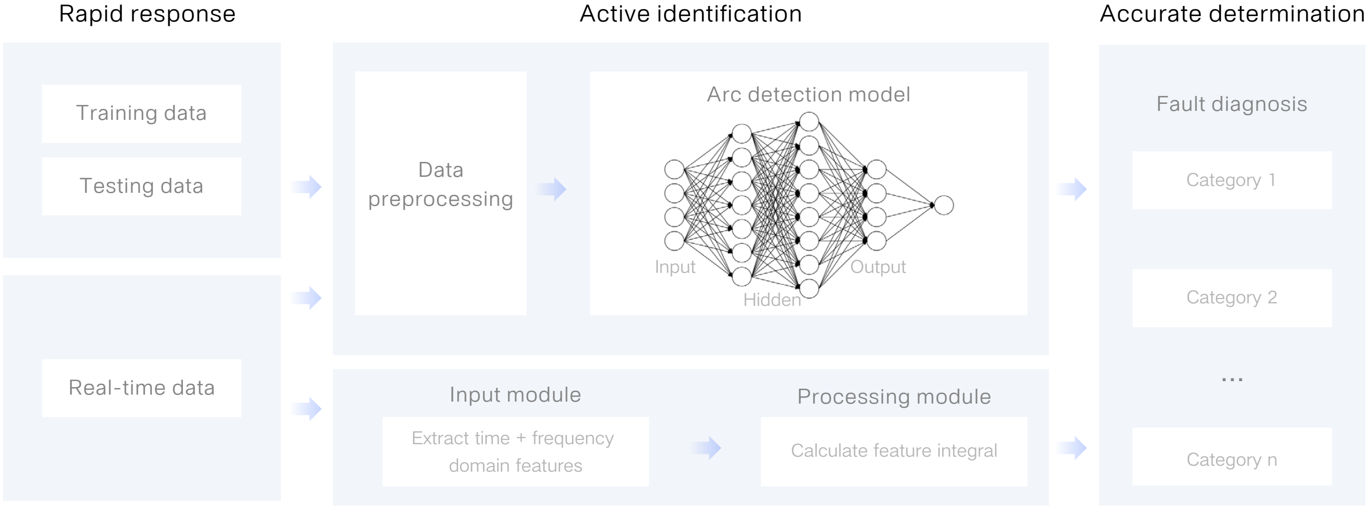


Figure 14: ArcDefender™ arc identification algorithm framework

3. Rapid arc extinguishing

SUNGROW leverages the deep integration and data exchange between PCS and battery. When the system detects a risk of arcing, the PCS quickly develops strategies and issues arc extinguishing instructions. It actively suppresses and shuts down waves to achieve efficient and accurate arc extinguishing.

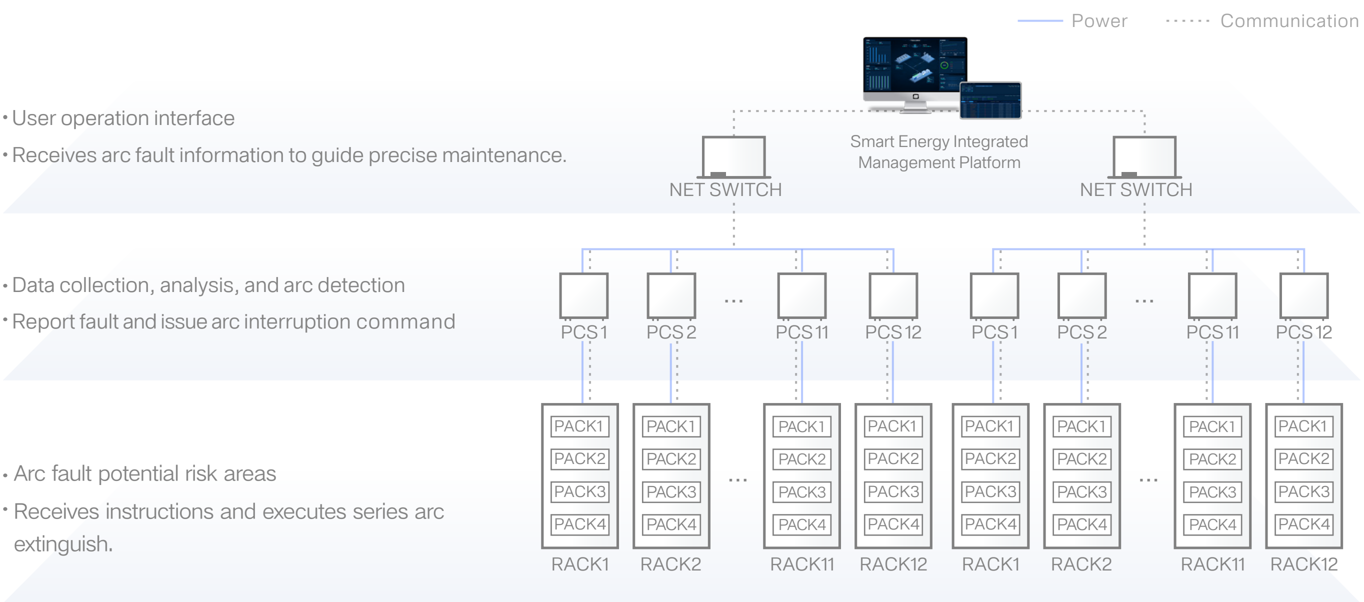


Figure 15 ESS ArcDefender™ technology network diagram⑥

⑥ The network diagram refers to PowerTitan2.0 energy storage system

3.2 Advantages of the Solution

SUNGROW ESS ArcDefender™ technology has demonstrated excellent and stable performance in actual tests. It can accurately identify arc events at a maximum current level of 210A and cover various arc incidents within a maximum energy range of 1500J.

1. Guide efficient operations and reduce maintenance costs

SUNGROW provides early warnings for insulation risks and guides O&M personnel in identifying potential faults and carrying out preventive maintenance. For arcing faults, the system rapidly recognizes and locates the arcing fault points in milliseconds, reducing unnecessary inspection and repair time for O&M personnel and lowering maintenance costs.

2. High-standard risk control to enhance system reliability

The arc detection accuracy is 100%, with zero false alarms and zero omissions. It quickly interrupts the power within 0.2 seconds, preventing broader damage caused by arcing and ensuring the safety of lives and assets.

C4

Verification and Evaluation of ArcDefender™ Technology

4.1 Application Requirements and Technical Solution Review

In order to fully understand the performance of SUNGROW ESS ArcDefender™ technology, a comprehensive validation and evaluation was conducted by CGC and TUV Rheinland verification team in May 2024, commissioned by SUNGROW.

01 Demand analysis

Review and analysis

· Clarity of areas and scenarios where arc risks exist · Appropriateness of determined application requirements

· Suitability of formulated response strategies

Review method: Document review

02 Solution review

Evaluation content

· Clarity of expected protection and achievement goals

· Meeting predetermined target requirements (including basic function response, achieved protection range, supported working modes, and anti-interference conditions), response time, etc.

· Capability of the adopted technical solution to achieve expected goals, such as hardware configuration, software strategy, system protection design, etc.

Evaluation method: Document review + on-site verification

03 Function verification

On-site verification

· Detection range (coverage of detection and protection) · Supported system types (different system structures)

· Response accuracy (precision of protection time and energy) · Supported working modes

· Types of anti-interference measures

Verification method: Witness test

04 Performance evaluation

Evaluation content

· Compliance of technical solution and performance indicators with specified levels in existing standards

· Technological advancement and its adaptability to application prospects

· Potential for technological innovation

4.2 Performance Verification and Results ⑦

The test comprehensively considered the actual application scenarios of ESS, validating the equipment under grid-connected, off-grid, charging, and discharging modes. It supported both single-branch and dual-branch system types, covering totally 45 operating conditions, including basic functions and anti-interference capabilities under different arc current conditions. See Figure 16 for details. Due to limited space, this white paper only presents the experimental process and results for selected conditions:

Operating modes	System types	Test location	Minimum arc current (A)	Detection module working current (A)	Arcing rate (mm/s)	Arc spacing (mm)
On/Off-Grid	Single-branch	Positive/Middle /Negative	0.1Imax	0.1Imax	5.0	1.5
On/Off-Grid	Single-branch	Positive/Middle /Negative	0.3Imax	0.3Imax	5.0	2.5
On/Off-Grid	Single-branch	Positive/Middle /Negative	0.5Imax	0.5Imax	5.0	2.5
On/Off-Grid	Single-branch	Positive/Middle /Negative	Imax	Imax	5.0	2.5
On/Off-Grid	Dual-branch	Positive/Middle /Negative	0.5Imax	Imax	5.0	2.5

Figure 16 Key parameters of 45 operating conditions experiments

1. Grid-connected charging mode

Working current of arc starting circuit	Total current	Test location	Working voltage (V)	Arcing rate (mm/s)	Arc spacing (mm)	Arc energy (J)	Breaking time (ms)
0.5Imax	0.5Imax	Positive	1299	5.0	2.5	118.3	55

Figure 17 Waveform diagram for the corresponding condition

⑦ In the waveform, Ch1- represents arc current, Ch2- represents the output current of PCS AC side, Ch3- represents arc voltage, Ch4- represents the voltage at both ends of the PCS DC side

2. Grid-connected charging single-branch maximum current mode

Working current of arc starting circuit	Total current	Test location	Working voltage (V)	Arcing rate (mm/s)	Arc spacing (mm)	Arc energy (J)	Breaking time (ms)
Imax	Imax	Positive	1310	5.0	2.5	169	47

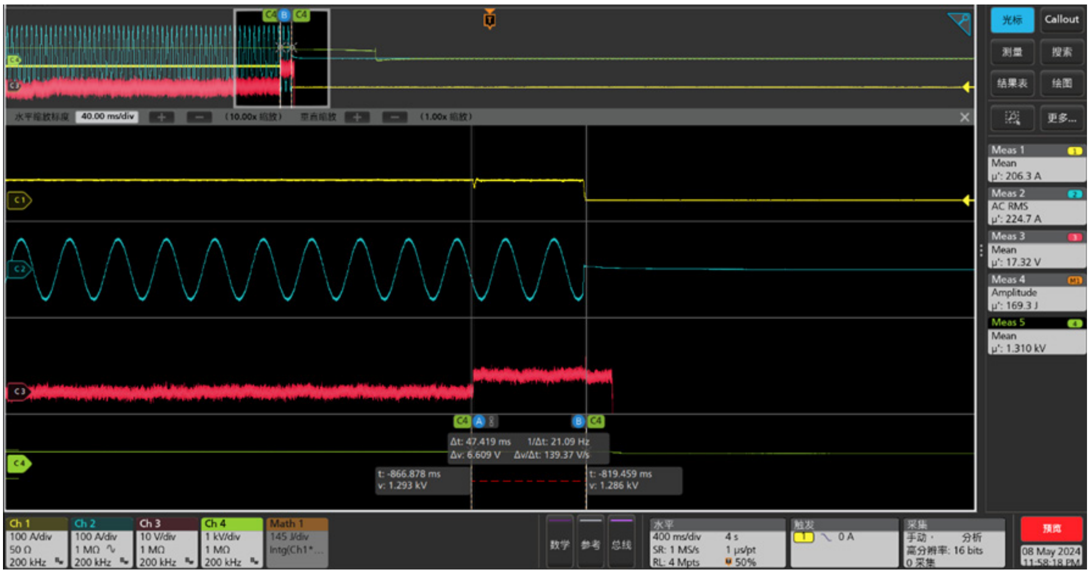


Figure 18 Waveform diagram for the corresponding condition

3. Grid-connected charging dual-branch maximum current mode

Working current of arc starting circuit	Total current	Test location	Working voltage (V)	Arcing rate (mm/s)	Arc spacing (mm)	Arc energy (J)	Breaking time (ms)
0.5Imax	Imax	Middle	1307	5.0	2.5	114	141

Figure 19 Waveform diagram for the corresponding condition

4. Off-grid discharging single-branch mode

Working current of arc starting circuit	Total current	Test location	Working voltage (V)	Arcing rate (mm/s)	Arc spacing (mm)	Arc energy (J)	Breaking time (ms)
0.3Imax	0.3Imax	Positive	1204	5.0	2.5	79	72

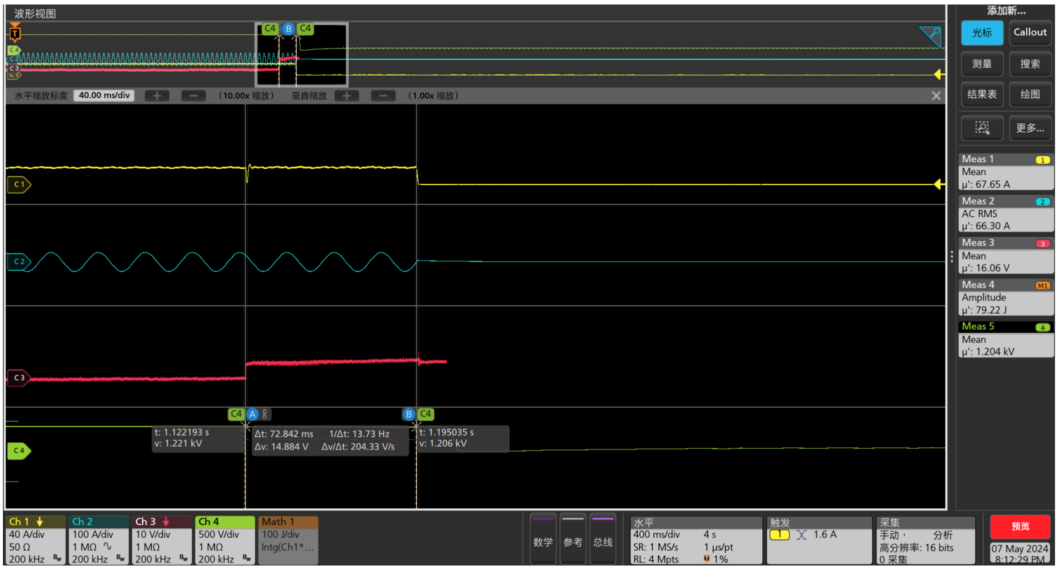


Figure 20 Waveform diagram for the corresponding condition

In response to industry development needs, CGC, in collaboration with other relevant stakeholders such as SUNGROW and TUV Rheinland, has conducted extensive research and discussions to formulate the CGC/GF 240:2024 “Technical Specification for DC Arc Detection and Breaking Evaluation of ESS” (hereinafter referred to as the “Technical Specification”). This specification details the testing methods and evaluation standards. Addressing future needs for ESS technology, it sets higher requirements across broader evaluation dimensions. For detailed graded evaluation requirements of core performance in arc detection and interruption technology, see Figure 21.

Requirements	Level 1	Level 2	Level 3	Level 4	Level 5
Detectable arc types	Series arc				Reserved (according to arc type and other anti-interference capabilities, etc.)
Detectable fault locations	Between PCS positive electrode, negative electrode and battery module				
Adaptable working scenarios	On-grid	On-grid	On-grid, off-grid (resistive load, etc.)	On-grid, off-grid full coverage	
Supported system types	Single input	Double branch	Double branch	Double branch	
Arc detection accuracy	80%	90%	100%	100%	
Number of arc detection false	2	1	0	0	
Breaking time	1s	0.5s	0.3s	0.2s	
Arc energy	＜7500J	＜3750J	＜2250J	＜1500J	
Max. adaptable working current	0.9Imax	1.0Imax	1.0Imax	1.0Imax	

Figure 21 Technical Specification for Core Performance Grading Evaluation Requirements of Energy Storage Arc Detection and Breaking Technology

According to the “Technical Specification”, the verification team conducted on-site testing and verification on the PCS products that adopted ESS arc detection and breaking technology in accordance with the above evaluation requirements, and obtained the following verification results:

Items	Results
Detectable arc types	Series arc
Detectable fault locations	Between PCS positive electrode, negative electrode and battery module
Adaptable working scenarios	On-grid, off-grid full coverage
Supported system types	Single/double branch
Arc detection accuracy	100%
Number of arc detection false	0
Breaking time	< 0.2s
Arc energy	< 1500J
Max. adaptable working current	1.0Imax
Rating results	Level 4

Figure 22 Verification results of ESS arc detection and breaking technology for solar power supply

4.3 Comprehensive Evaluation

Based on the test and validation results, SUNGROW ESS ArcDefender™ technology achieved a “Level 4” performance rating according to the CGC/GF 240:2024 “Technical Specification for DC Arc Detection and Breaking Evaluation of Energy Storage Systems”:

(1) With high sensitivity and fast response capability, it effectively prevents the occurrence of arc hazards;

(2) By utilizing advanced detection algorithms and intelligent analysis systems, precise identification and determination of arc faults can be achieved;

(3) After strict laboratory certification and practical application verification, the certification and application results have proven the effectiveness and reliability of this technology.

Figure 23 Level 4 Certification

Figure 24 ArcDefender™ technology successfully applied in Huaneng Longteng ESS project

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Conclusion and Outlook

Building upon the deep integration of electrochemistry, power electronics, and grid support technologies, SUNGROW leverages AI technologies such as data analysis and machine learning to create an integrated and professional ESS. Through continuous innovation in areas such as comprehensive cell management, ESS arc detection and suppression, and Rack-level protection, SUNGROW enhances system operational efficiency and reliability while ensuring safety.

Furthermore, SUNGROW actively promotes collaboration with the industry to enhance the top-level design of safety systems. We are committed to strengthening the development and application of basic research and underlying support technologies. By progressing together with the industry, SUNGROW aims to create safer and more reliable ESS , contributing to the global energy transformation.

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