Huawei Inverter Lifetime Report

Inverters models : SUN2000-12-150KTL

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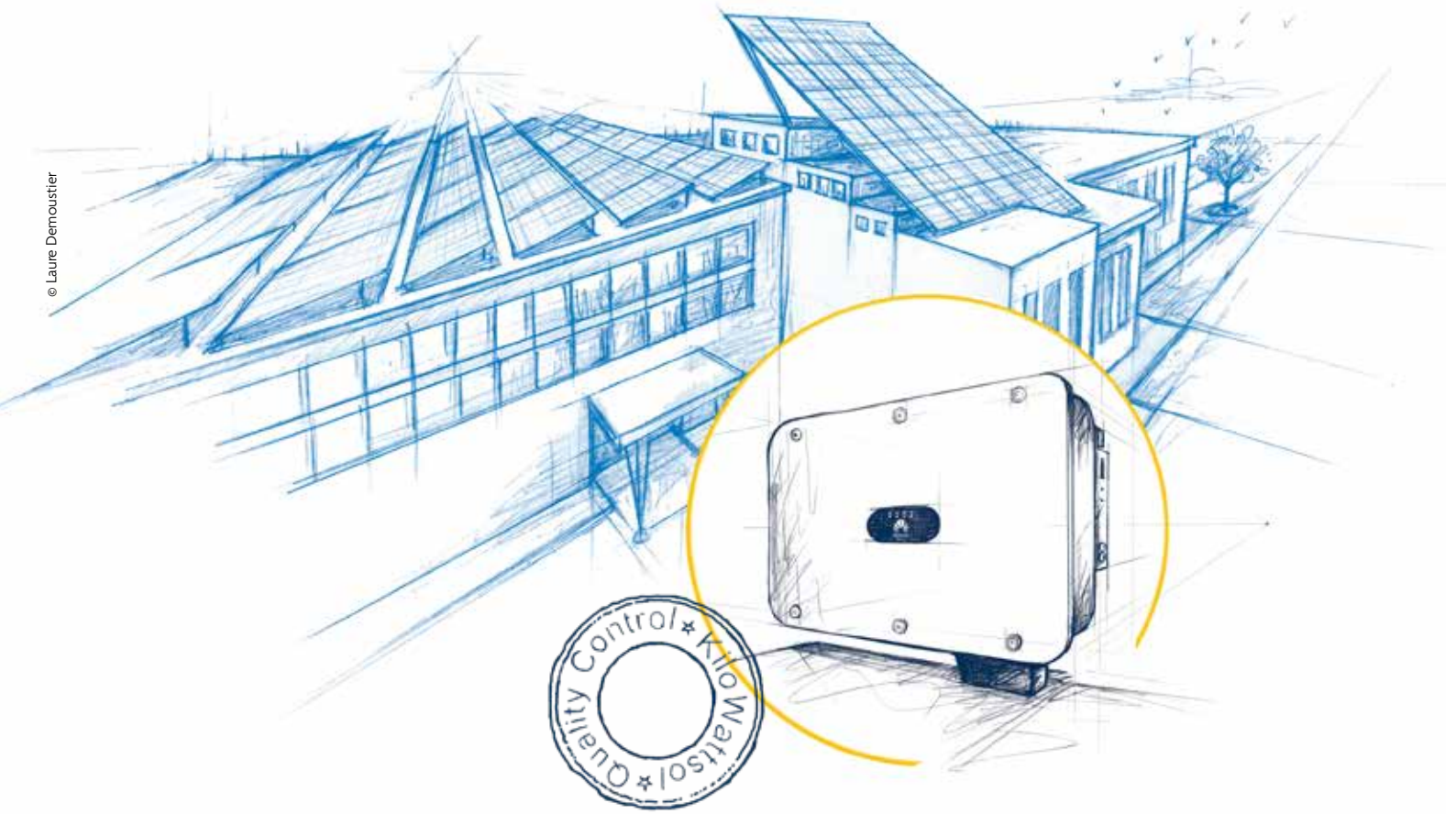

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SOLAR EXPERT

In collaboration with

HUAWEI

Rooftop PV plant

Executive summary

Today's financial models for solar projects are based on increasingly long timeframes, which can exceed 30 years. The central objective of this report is to challenge the resilience of Huawei's SUN2000 C&I series of inverters and verify its ability to reliably operate for around 25 years.

Assessing an inverter's longevity entails an examination of the manufacturer's proficiency and quality standards, which directly impact manufacturing processes, component durability, the inverter's resilience to common faults, and its performance during reliability tests. This report thoroughly explores these aspects to validate the SUN2000 C&I series of inverter's ability to endure for approximately 25-year.

Huawei, a global technology giant, has firmly established its strong presence in the string inverter market, underpinned by financial stability and an unwavering dedication to innovation.

After numerous iterations informed by extensive practical experience, coupled with a strong dedication to continuous innovation, Huawei crafted a solution that addresses the most prevalent defects and extends its inverter's lifetime.

The products adhere to operational protocols aligned with internationally recognized quality standards. Leveraging extensive expertise and a strong commitment to quality and innovation, these measures significantly enhance the long-term reliability of the inverters and prolong their operational lifespan.

A meticulous vetting process and rigorous testing protocols consistently affirm that the chosen components have a projected lifetime of 25 years. The SUN2000 C&I series of inverters themselves has undergone a battery of comprehensive tests, both within Huawei's advanced facilities and through external third-party assessments, ensuring product reliability and conformity.

In light of these cumulative strengths, we express our utmost confidence that the SUN2000 C&I series of inverter are a reliable, enduring solution, capable of consistently performing for around 25 years. Huawei's wealth of experience and unwavering commitment to quality, innovation, and rigorous testing has positioned the manufacturer as a leading force in the global inverter market.

Abbreviations & acronyms

ACRONY	DESCRIPTIO
AC	Alternative Current
AFCI	Arc Fault Circuit Interrupter
BCG	Boston Consulting Group
C&I	Commercial and Industrial
CAGR	Compound Annual Growth Rate
DC	Direct Current
EU	European Union
GCTC	Global Compliance & Testing Center
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IGBT	Insulated-gate bipolar transistor
IMD	Insulation Monitor Device
IP66	Ingress Protection66
ISO	International Organisation for Standardization
JEDEC	Joint Electron Device Engineering Council
JRC	Joint Research Centre
KWS	kiloWattsol
LVRT	Low Voltage Ride Through
MBUS	Meter-Bus
MPPT	Maximum Power Point Tracker
PCB	Printed Circuit Board
PLC	Programmable Logic Controller
PV	Photovoltaic
R&D	Research and Development
RS485	Recommended Standard485
RSD	Rapid Shutdown
SCADA	Supervisory Control and Data Acquisition
SCLD	Smart Connector Level Detection
SSLD	Smart String-Level Disconnector
SSCF-TECH	Smart Self Clean Fan - Technology
TUV	Technical Inspection Association
WLAN	Wireless local-area network

Table of content

1. Introduction

Objective of the Report

A 15-year lifetime is generally considered as a maximum for solar in the industry, but, like for modules, the quality of inverters has greatly improved over the last few years. As a global leading inverter manufacturer, Huawei ('the Client' or 'the manufacturer') is willing to demonstrate the reliability of its equipment to its customers.

For this purpose, Huawei has enlisted the help of kiloWattsol (KWS), as an independent third party photovoltaic (PV) expert, to provide a report demonstrating a lifespan of approximately 25 years for its SUN 2000 C&I series of inverters. This analysis is based on a desk review.

This report exclusively examines the factors that influence the inverter's lifespan. It does not delve into any other aspects of the product.

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Caveat

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Versions

Version	Date	Recipients	Modification
V1.4 - En	02/09/2024	Huawei France	Final version

Context

Today's financial models for solar projects are based on increasingly long timeframes, which can exceed 30 years. For many years, the focus was on solar modules' lifespan expectancy and guaranteed performance. Very quickly the threshold was set to 20 years and, in the case other components would fail before this date, a replacement was provisioned in the business models.

With bifacial and glass-glass structures, modules' lifespan was extended to 30 years. The massive embrace of string inverters by the industry also changed the design of photovoltaic (PV) plants, reducing the number of sub-components to the bare minimum: modules, inverters and transformers.

The global solar market has been consistently expanding, with an average compound annual growth rate of 30% over the past decade. Simultaneously, the solar industry for both modules and inverters has become highly concentrated. As a result, all stages of their assembly are necessarily highly automated and subject to rigorous quality control processes.

Of all components in a solar project, the inverter is undoubtedly the device that has undergone the most significant technical evolution over the last 20 years, evolving from a simple electrotechnical converter to a highly digitalised piece of equipment, capable of decomposing and recomposing the energy produced by increasingly powerful modules, into an electrical signal linked to the constraints of the grid.

Inevitably, these technological evolutions have an impact on the lifespan of such equipment, and investors need factual information to support the associated economic assumptions in their financial models.

As a Technical Advisor and trusted third party, we present in this report our assessment of the SUN2000 C&I series of inverters lifetime.

To assess the lifetime of an inverter in advance, one must look at the manufacturer's experience and its manufacturing process, as well as the product. Hence, in this report, we assess Huawei's experience as a solar inverter manufacturer, the quality assurance of its manufacturing process, the design of the SUN2000 series of inverters and the results of technical tests they have undergone.

Pic. 2.

Huawei's headquarter

2. Company Overview

This chapter of the report presents Huawei as a company, including a brief history and its position in the market.

Global Presence

COMPANY OVERVIEW

Established in 1987, Huawei is a prominent global leader in information and communications technology (ICT) infrastructure and smart devices. With a workforce of approximately 207,000 employees, the company operates in over 170 countries and regions, delivering services to over three billion people worldwide.

Pic. 3.

Huawei's Fab Site

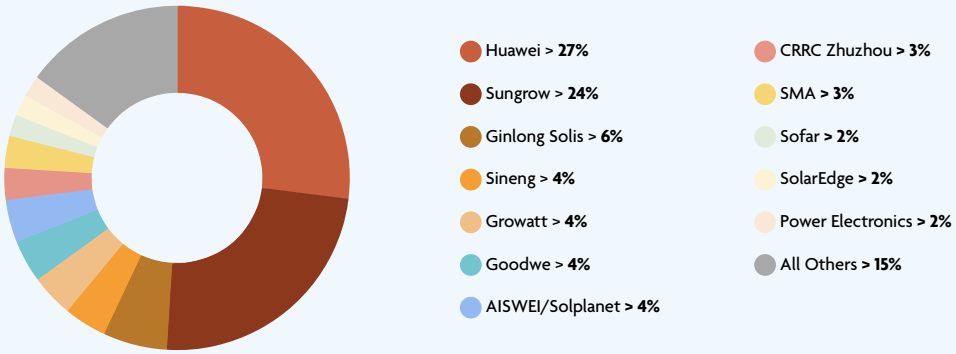
MARKET PRESENCE

Huawei's strong presence in the market is undeniable. In 2023, as reported by Wood Mackenzie, the company's leading position was consistently maintained, with a 27% market share being secured. This surpassed competitors like Sungrow (24%) and Ginlong Solis (6%). Huawei's noticeable presence is underscored by its manufacturing capacities of 180 GW per year and its unwavering commitment to innovation.

The analysis conducted by Wood Mackenzi[1] revealed that Huawei experienced a substantial 48% increase in shipments in 2023 compared to the previous year. Additionally, the company demonstrated consistent business growth, achieving a total worldwide shipment of over 500 GW.

1 Annie Rabi Bernard ,Wood Mackenzie" ,Global solar PV inverter and module-level power electronics market share"2023

Global PV inverter market share rankings by shipment, 2023 source: Wood Mackenzie



Rapid and Sustainable Growth

HUAWEI'S EVOLUTION

In just over a decade since entering the AC/DC energy conversion sector in 2007, Huawei has established itself as a key player in the industry. The company has consistently expanded its production capabilities and demonstrated impressive growth, achieving a compound annual growth rate (CAGR) of 25% between 2017 and 2022. This steady progress highlights Huawei's strong financial foundation and ongoing commitment to innovation.

FINANCIAL STABILITY

Green and low-carbon solutions are providing new momentum for sustainable development. Industries are also embarking on a new journey that combines digital, intelligent, and green transformation. At the heart of these transformations, Huawei has built its success based on its unwavering focus on R&D, its ability to meet customers' needs with tailored solutions, and its achievement of cost-effectiveness without compromising quality. It earned Huawei the status of an innovative and pioneering company, generating a revenue of over $99.4 billion in 2023.

Huawei's revenues in 2022 and 2023

Year	2023	2022	YoY
Revenue (US$ billion)	99.44	90.71	9.6

Its Digital Power business is also working to drive the transition to renewable energy in all industries by focusing on areas like clean power generation, mobility electrification, and green ICT power infrastructure. By the end of 2023, Digital Power's solutions have helped customers generate 997.9 billion kWh of green power and save 46.1 billion kWh of electricity. These efforts resulted in a reduction of 495 million tons in CO2 emissions.

Global Reach, Experience, and Innovation

GLOBAL REACH AND WEALTH OF EXPERIENCE

Huawei's extensive global presence is not just a matter of geography; it is a wellspring of invaluable experience that continuously informs and enhances its product offerings. Operating in more than 170 countries, the company has navigated diverse markets, regulatory landscapes, and customer demands. This expansive network, spanning the globe, has enriched Huawei's understanding of global dynamics, enabling the company to tailor its products and solutions to meet the unique needs of various regions.

Huawei's commitment to innovation and manufacturing excellence is deeply intertwined with its international experience. The wealth of knowledge amassed from diverse cultural contexts and technical challenges has enabled Huawei to refine and adapt its products to an unparalleled degree. Each market served has provided valuable insights, inspiring constant improvements and adjustments that have become hallmarks of Huawei's product development approach.

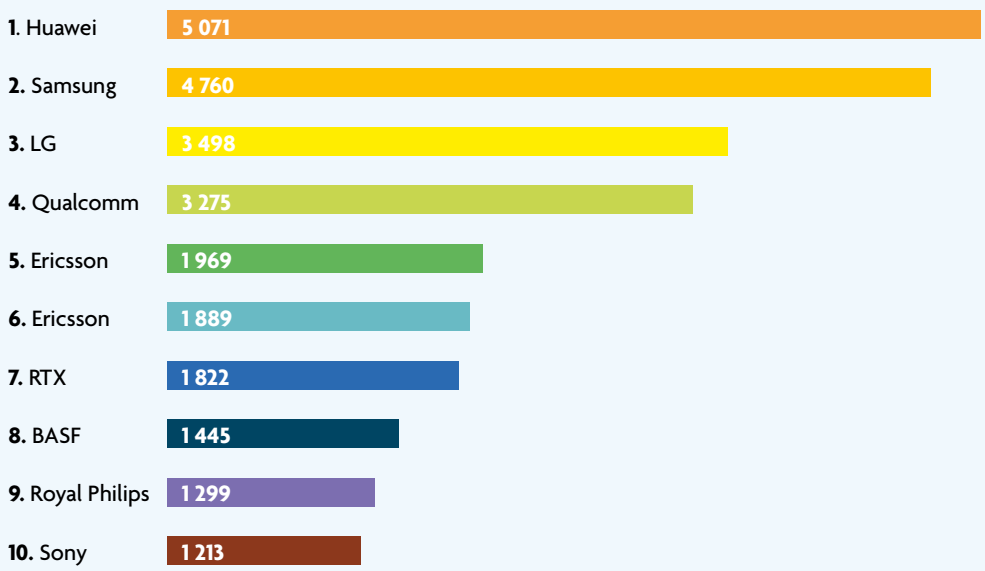
INNOVATION AND R&D

Innovation lies at the heart of Huawei's success, and this innovation is profoundly informed by the global perspective it has gained through its extensive presence. With 23.4% of its sales revenues reinvested into research and development (R&D), Huawei ranked 5th in the 2023 EU Industrial R&D Investment Scoreboard. According to Boston Consulting Group (BCG), Huawei is the world's 8th most innovative company.

The company's 114,000+ R&D employees, over 55% of its total workforce, have contributed to a portfolio of more than 140,000 active patents by the end of 2023. Huawei operates numerous R&D centres around the world, each uniquely positioned to harness local expertise while contributing to the company's global innovation ecosystem.

In recent years, Huawei has consistently demonstrated its commitment to innovation and research. In 2021, it was recognised as the second-largest global R&D investor by the EU Joint Research Centre (JRC). In 2023, it was first in terms of patent applications according to the European Patent Office (see graph).

Huawei comes #1 in Patent applications with European Patent Office in 2023



Pic. 4.

Huawei Site

Conclusions and Key Insights

Huawei's journey, from its inception in 1987 and has led to its current standing as a global technology giant, is marked by rapid growth, financial stability, and an unwavering dedication to innovation.

Huawei's impressive trajectory extends beyond financial success to encompass its consistent ability to produce top-tier, products. Bolstered by a growing presence in the photovoltaic industry and a deep reservoir of practical knowledge, Huawei stands as a pivotal player.

Huawei's reputation for delivering cost-efficient quality products is a testament to its profound understanding, forged through global engagements and sustained investments in research and development.

3. Products Description

Huawei's C&I inverters product line have rated power ranging from 12 kW to 150 kW. They also incorporate MPPT circuits to track the maximum PowerPoint of the PV strings. The SUN2000-12-25KTL-MB0 series of inverters is a hybrid range that also features a DC input for residential storage.

The following table shows the different models of the C&I series.

Model	Nom. Power [kW]	Number of MPPT	Number of Inputs
SUN2000-12KTL-M5	12	2	4
SUN2000-15KTL-M5	15	2	4
SUN2000-17KTL-M5	17	2	4
SUN2000-20KTL-M5	20	2	4
SUN2000-25KTL-M5	25	2	4
SUN2000-12KTL-MB0	12	2	4
SUN2000-15KTL-MB0	15	2	4
SUN2000-17KTL-MB0	17	2	4
SUN2000-20KTL-MB0	20	2	4
SUN2000-25KTL-MB0	25	2	4
SUN2000-30KTL-M3	30	4	8
SUN2000-36KTL-M3	36	4	8
SUN2000-40KTL-M3	40	4	8
SUN2000-50KTL-M3	50	4	8
SUN2000-100KTL-M2	100	10	20
SUN2000-115KTL-M2	115	10	20
SUN2000-150KTL-MG0	150	7	21
SUN5000-150KTL-MG0	150	7	12

Key Features

ELECTRICAL CHARACTERISTICS

The SUN2000 series is a three-phase grid-tied PV string inverter engineered to seamlessly convert the DC power generated by PV strings into AC power, ready for integration into the electrical grid. The inverters have a European efficiency ranging between 97.9% and 98.4%.

The main electrical characteristics of the C&I SUN2000 series of inverters are presented in the following table.

Model	Efficiency	Input	Output		General
	European efficiency	Max PV input per MPPT	Nom. AC active power [kWc]	Max AC active power [kVA]	Cooling method
SUN2000-12KTL-M5	97.9%	2	12	13.2	smart air cooling
SUN2000-15KTL-M5	98.0%	2	15	16.5	smart air cooling
SUN2000-17KTL-M5	98.1%	2	17	18.7	smart air cooling
SUN2000-20KTL-M5	98.1%	2	20	22	smart air cooling
SUN2000-25KTL-M5	98.2%	2	25	27.5	smart air cooling
SUN2000-12KTL-MB0	97.9%	2	12	13.2	smart air cooling
SUN2000-15KTL-MB0	98.0%	2	15	16.5	smart air cooling
SUN2000-17KTL-MB0	98.1%	2	17	18.7	smart air cooling
SUN2000-20KTL-MB0	98.1%	2	20	22	smart air cooling
SUN2000-25KTL-MB0	98.2%	2	25	27.5	smart air cooling
SUN2000-30KTL-M3	98.4%	2	30	33	natural convection
SUN2000-36KTL-M3	98.4%	2	36	40	natural convection
SUN2000-40KTL-M3	98.4%	2	40	44	natural convection
SUN2000-50KTL-M3	98%	2	50	55	smart air cooling
SUN2000-100KTL-M2	98.4%	2	100	110	smart air cooling
SUN2000-115KTL-M2	98.4%	2	115	125	smart air cooling
SUN2000-150KTL-MG0	98.4%	3	150	165	smart air cooling
SUN5000-150KTL-MG0	98.4%	3	150	165	smart air cooling

Products Description

OPERATIONAL VERSATILITY

Designed to perform in a wide range of environmental conditions, the SUN2000 C&I series of inverters boasts an impressive operating temperature range, spanning from -25°C to +60°C.

Its air-cooling system ensures efficient heat dissipation, enabling reliable operation across diverse climates.

COMMUNICATION AND SAFETY

The SUN2000 C&I series of inverters prioritises safety and efficient communication. It is engineered to support a multitude of communication interfaces, facilitating efficient data management. These interfaces encompass RS485, MBUS, and WLAN, complemented by a dedicated mobile application tailored for monitoring and control purposes.

The following table shows the communication interfaces in each model.

Communication and safety

	RS485	MBUS	WLAN	Mob APP
SUN2000-12-25KTL-M5	x	-	x	x
SUN2000-12-25KTL-MB0	x	-	x	x
SUN2000-30-36-40KTL-M3	x	-	x	x
SUN2000-50KTL-M3	x	x	x	x
SUN2000-100KTL-M2	x	x	x	x
SUN2000-115KTL-M2	x	x	x	x
SUN2000-150KTL-MG0	x	x	x	x
SUN5000-150KTL-MG0	x	x	x	x

x : present **-** : missing

The inverter is also equipped with an array of protection features, with several being uniquely tailored to Huawei products. For instance:

The Smart String-Level Disconnector (SSLD) is a standout feature, designed to precisely identify faults originating from the DC side of the PV system. This includes issues like reverse polarity connections, backflow currents, and short circuits. Importantly, it executes automatic string-level shutdowns within milliseconds, significantly enhancing the active safety capacity of the PV plant and preventing potential damage to the inverter.

The AC Overcurrent Protection is vigilant in monitoring current flow, promptly detecting excessive currents to curtail temperature rises within circuit conductors, thus safeguarding the equipment from harm.

The DC Reverse-polarity Protection ensures the proper functioning and integrity of sensitive electronic components within the inverter.

The PV-array String Fault Monitoring is a crucial feature that detects and promptly reports faults within PV strings. This capability enables swift corrective action, ensuring the PV system operates optimally and minimising the risk of stress on its functionality.

Type II DC and AC Surge Arresters offer additional protection by diverting excessive voltage to the ground, thus averting potential damage caused by voltage spikes. This ensures the inverter's reliable operation, even under adverse conditions.

The smart PV controller enables the identification of grid faults and ensures stable operation following a successful Low Voltage Ride Through (LVRT) procedure. It maximizes energy production, ensures system safety, facilitates smooth grid interaction, and provides valuable data for ongoing system optimization and user engagement.

The Rapid Shutdown (RSD) feature is engineered to safeguard against overheating and surges within the inverter, ensuring optimal safety and performance. With the continuous advancement of solar technology, PV modules are frequently exposed to high voltage, increasing the risk of surges and overheating, which can jeopardise safety and device integrity. By integrating the RSD function, the inverter not only guarantees longevity but also delivers consistent and reliable performance, even in demanding conditions.

Addressing another critical concern, the Arc Fault Circuit Interrupter (AFCI) function tackles the challenge of arc fault detection, a prevalent issue in PV inverters. This functionality effectively prevents device damage stemming from arc faults.

Products Description

Furthermore, the inverter boasts an IP66 Protection Level, alongside Anti-Islanding Protection, DC Insulation Resistance Detection, AC Grounding Fault Protection, Residual Current Monitoring Unit and more. These comprehensive protection features not only enhance the longevity of the inverter but also reinforce its robust performance.

The following table presents the protection features of the C&I SUN2000 series of inverter.

	SSLD	AC Overcurrent protection	DC reverse polarity protection	PV array String fault monitoring	Type II DC and AC surge protection	Smart PV controller	RSD	AFCI
SUN2000-12-25KTL-M5	-	x	-	x	x	x	x	x
SUN2000-12-25KTL-MB0	-	x	-	x	x	x	x	x
SUN2000-30-36-40KTL-M3	-	x	-	x	x	x	x	x
SUN2000-50KTL-M3	-	x	-	x	x	x	x	x
SUN2000-100KTL-M2	x	x	x	x	x	x	-	x
SUN2000-115KTL-M2	x	x	x	x	x	x	-	-
SUN2000-150KTL-MG0	x	x	x	x	x	x	-	x
SUN5000-150KTL-MG0	x	x	x	x	x	x	x	x

x : present **-** : missing

A more detailed breakdown of these features can be found in the next chapter.

SUN2000-100KTL-M2 Communication cables

SUN2000-115KTL-M2

Pic. 7.

PV plant

4. A Multi-Faceted Approach to Enhancing Inverter Longevity

Common Inverter Failures

Burned DC combiner Box

DC Fuses in PV plants

Inverters are essential components in PV systems. Their primary function is to convert the direct current (DC) voltage generated by solar panels into usable alternating current (AC) power, which is essential for most applications. This AC power is then sent out for consumption or fed into the electrical grid.

Fundamentally, every inverter comprises a complex array of electronic components, constituting its foundational framework. This assemblage is energised via the power board, creating a direct link with input terminals, where they draw electrical energy from the PV system. This orchestration ensures the seamless conversion and transmission of electrical energy, enabling the functionality that underpins the inverter's operations.

Moreover, the communication board within the inverter plays a pivotal role, acting as the messenger that relays crucial production data to a Supervisory Control and Data Acquisition (SCADA) system. In the context of PV systems, SCADA systems are the watchful overseers, tasked with monitoring and controlling various facets of the operation. They grant operators real-time insights, enabling them to make informed decisions and execute remote control over PV operations.

A Multi-Faceted Approach to Enhancing Inverter Longevity

As with any electronic device, the intricate components within the inverter, comprising the input board, output board, power board, and communication board, generate heat during operation. Preserving their reliability and functionality becomes paramount, necessitating the integration of efficient cooling systems within the inverter. This cooling mechanism serves as a safeguard against overheating, ensuring the optimal performance and longevity of these critical components. All these intricate elements are housed within a protective casing, shielding the inverter's internal workings from external environmental factors.

The lifespan of a solar inverter hinges on a combination of factors, encompassing its design, component quality, maintenance practices, and operating conditions.

Over time, like all electronic equipment, inverters naturally degrade. However, with meticulous design and maintenance, a well-crafted inverter should enjoy a lengthy operational life. The quality of components used within the inverter holds significant sway over its longevity. Opting for high-quality electronic elements, including capacitors, semiconductors, and transformers, can mitigate the effects of ageing.

The operating environment in which the solar inverter operates also has an impact on its lifespan. Exposure to extreme temperatures, humidity, and environmental elements can accelerate wear and tear. Hence, inverters must be engineered to withstand the specific environmental conditions to which they will be exposed during their operational life.

As stated earlier, inverters, by their very nature, generate heat while in operation. Therefore, implementing effective cooling and ventilation mechanisms is essential to dissipate this heat efficiently. Inadequate thermal management can lead to overheating, ultimately diminishing the inverter's lifespan. Ensuring that the inverter operates within its rated capacity and avoids conditions conducive to overheating is crucial.

Additionally, the quality of the initial installation bears immense significance. Adhering to proper wiring practices, grounding procedures, and safety standards is pivotal to ensure that the inverter functions as intended and avoids potential electrical issues.

A Multi-Faceted Approach to Enhancing Inverter Longevity

The most common sources of failures are described below:

1. **Overheating:** Overheating can be caused by high ambient temperatures, overloading, internal issues (dust accumulation, component failure) or inadequate cooling. Inverters generate heat while converting DC to AC power. Over time, this heat can cause components to degrade or fail. Inadequate cooling or ventilation can exacerbate this issue.

2. **Electrical Component Failures and ageing:** Components such as capacitors, diodes, and transistors may fail due to manufacturing defects, age, or excessive voltage or current levels. These components are essential for the smooth operation of the inverter. Problems with the AC output, such as voltage fluctuations, harmonic distortion, or waveform distortion, can occur and may be caused by internal inverter faults. Like any electronic equipment, inverters have a limited lifespan. As they age, their components can degrade, leading to a gradual decrease in performance or complete failure.

3. **Isolation Faults:** Inverters need to isolate DC and AC circuits for safety reasons. If there is a fault in the isolation mechanism, it can lead to electric shocks or fires.

4. **Grid Connection Failures:** Inverters are designed to synchronise with the grid. If there's a failure in grid connection, the inverter may not operate correctly or may shut down to prevent feeding power back into the grid during an outage.

5. **Communication Failures:** Many modern inverters are equipped with monitoring and communication features to relay information about system performance. Communication failures can make it challenging to monitor and diagnose issues.

6. **Environmental Factors:** Exposure to extreme weather conditions, moisture, dust, or pests can damage the inverter's components or electronics, leading to failures. Inverters are often installed outdoors, where they are exposed to daily and seasonal temperature variations. These fluctuations can cause expansion and contraction of materials, which, over time, may lead to mechanical stress, solder joint failures, or other thermal-related issues.

7. **Surge and Lightning Damage:** Inverters can be vulnerable to power surges or lightning strikes, which can cause irreparable damage to the circuitry.

8. **Installation Errors:** Poor installation practices, including incorrect wiring, insufficient grounding, or inadequate protection from environmental factors, can lead to inverter failures.

Huawei's Strategies and Technologies for Long Term Reliability


Pic. 10.

Inverters in 2MW Japan Floating Plant


Pic. 11.

50MW China Solar-fishery Plant

Huawei has improved the safeguarded the inverter from the most common types of inverter failures in the following ways:

INTERNAL FACTORS

Overheating

PV plants are generally located outdoors, exposed to abundant solar radiation. Efficient cooling is crucial for maintaining the optimal operation of inverters, ensuring they operate within acceptable temperature ranges and preventing overheating, a common concern during an inverter's operational life. Traditional fans often fall short in terms of long-term reliability due to their limited lifespan, potentially leading to reduced power output or protective shutdowns.

IGBTs, a core component of inverters, are sensitive to temperature. Effective heat dissipation is key to inverter reliability and quality. Thus, a primary design concern for inverters is balancing environmental adaptation with efficient heat dissipation.

To address these challenges, SUN2000 inverters employ a natural cooling method with an internal fan that circulates air intermittently when the internal enclosure temperature exceeds 60°C. This design enables IP65/Type 4X protection, ensuring the inverter is fully sealed without any ventilators and operates with low noise. Consequently, SUN2000 inverters achieve high reliability, avoiding power derating or shutdown due to external cooling fan failures that compromise heat dissipation.

In addition, the SUN2000-150KTL-MG0 and SUN5000-150KTL-MG0 models are equipped with the SSCF-TECH (Smart Self Clean Fan - Technology). This advanced fan is equipped with a reverse rotation function for dust removal and consists of three integrated fans within a single frame. Notably, the SSCF-TECH eliminates the need for routine maintenance, enhancing convenience and reliability. Additionally, the fan's unique bottom-mounted air inlet design effectively prevents the ingress of particles while promoting efficient airflow. Huawei's

A Multi-Faceted Approach to Enhancing Inverter Longevity

commitment to durability and longevity is further demonstrated by the rigorous quality control applied to these long-life fans.

To ensure the reliability of these cooling fans, a comprehensive battery of tests is conducted, including extreme high and low-temperature trials, temperature cycling assessments, dust and humidity evaluations, salt spray tests, environmental exposure examinations, vibration analysis, irradiation testing, and corrosion gas assessments. These extensive tests provide solid evidence of the fan's resilience, even in challenging environments such as deserts and coastal regions.

Furthermore, the Rapid Shutdown (RSD) function protects the inverter against overheating, ensuring optimal safety and performance. This helps guarantee the inverter's longevity and reliable performance.

Electrical Component Failures and Ageing


Pic. 12.

High temperature test Setup


Pic. 13.

High temperature test Setup 2

One of the DC-side accidents of PV plants is electrical accidents of inverters. This can be caused by many factors such as DC Reverse Connection, Electrical Insulation Fault and DC/AC Terminal Contact Fault, leading to overheating and burning of the inverter. Huawei's recent inverters (starting from SUN2000-100KTL) have SSLD (Smart String Level Disconnection) technology with a precise fault detection which quickly disconnects DC system faults in less than a second. This technology meets IEC 60947-2 certification requirements, which test the required levels of safety and reliability according to international standards and end-user specifications. It has been delivered by DEKRA, a reputable certification body.

Component failures, including capacitors, diodes, and transistors, represent a common risk in the longevity of inverters. These failures may result from the natural ageing process or exposure to excessive voltage or current levels, and they are integral to the inverter's smooth operation. Similarly, issues on the AC output side, such as voltage fluctuations, harmonic distortion, or waveform distortion, can stem from internal faults within the inverter. Inverters, like all electronic equipment, have finite lifespans, and as they age, their components may degrade, leading to a gradual decline in performance or complete failure.

To mitigate the risk associated with component failures and ensure the extended lifespan of inverters, Huawei has implemented several advanced technologies in its smart PV inverter.

To enhance the reliability of the components on the PCB, the quality control plan divided into separate processes is put in place, ensuring that

specialized expertise is applied to each stage of the production. This also prevent any quality problem from evading detection.

Huawei's SUN2000 inverters use advanced design and rigorous testing to ensure the reliability of electrolytic capacitors. The patented design minimizes temperature rise within these capacitors by utilizing film capacitors to absorb high-frequency waves, keeping the temperature increase within 4°C. This approach extends the capacitors' lifespan to approximately 26 years at 50°C ambient temperature and up to 30 years at 60°C, assuming daily 8-hour full-load operation.

Film capacitors in the SUN2000 inverters are optimized for handling high voltage, surge, and ripple currents. The design ensures these capacitors can withstand operational stresses and maintain performance over extended periods.

The electric relays used in the SUN2000 inverters are selected based on stringent criteria to ensure long-term reliability. Huawei's R&D team conducts comprehensive evaluations to select relays that meet the inverters' 25-year design life span. These assessments include mechanical and electrical endurance tests, ensuring the relays can withstand frequent switching operations and environmental stresses.

Fans in the SUN2000 inverters are essential for maintaining optimal operating temperatures. The selected high-reliability fans have been tested for long-term operation under various environmental conditions, ensuring they can support the inverters' cooling requirements over the 25-year design life span. Accelerated life testing and real-world performance assessments validate their reliability

These technological innovations collectively contribute to the inverter's resilience, minimise the risk of component-related failures, and extend its operational life.

Communication Failures

Communication failures in inverters can significantly impede their functionality and monitoring capabilities, posing a risk to their longevity. These failures often result in the inverter's inability to report energy production, typically caused by malfunctioning displays, sometimes necessitating complete inverter replacement.

Huawei has addressed this common issue by equipping the C&I inverters starting from the SUN2000-50KTL with a Programmable Logic Controller (PLC) designed to enhance communication stability. This PLC feature offers several advantages:

1. Faster Transmission Rate: The PLC facilitates quicker data transmission, ensuring that information about system performance is relayed efficiently.
2. Longer Transmission Distance: With an extended transmission range, the inverter can communicate reliably even in scenarios with considerable distances between components.
3. Larger Array Support: The PLC's capabilities accommodate larger solar arrays, making it suitable for installations such as those in mountainous regions or expansive solar stations.

Additionally, the SUN2000 C&I series inverters are designed with a variety of communication interfaces to streamline data management. These interfaces include RS485, MBUS, and WLAN, and are supported by a dedicated mobile application to ensure efficient communication.

A Multi-Faceted Approach to Enhancing Inverter Longevity

Isolation Faults

Isolation faults within inverters, particularly those involving the failure to isolate DC and AC circuits as intended, pose significant safety risks, including the potential for electric shocks or fires. Such faults can lead to the deterioration of the inverter's performance and its overall longevity.

Huawei addresses this common issue by featuring the inverters with MPPT (Maximum Power Point Tracker)-level isolation with high positioning accuracy. This technology significantly reduces the risk of multi-point earth faults, enhancing fault detection and location precision.

Furthermore, Huawei addresses this common issue by implementing advanced technologies to enhance isolation and fault detection mechanisms. On the SUN2000-150KTL-MG0 and SUN5000-150KTL-MG0, the SCLD (Smart Connector Level Detection) technology employed in Huawei inverters serves to improve the reliability of DC connectors by promptly detecting abnormalities and taking appropriate actions, such as inverting alarms or shutting down the system to prevent the spread of faults when the connector temperature becomes irregular.

These innovative technologies minimise the likelihood of isolation faults that could jeopardise both the inverter's operational lifespan and overall system safety. These enhancements contribute to the longevity and effectiveness of Huawei's inverter technology in demanding operational environments.

Pic. 14.

Arc fault location

A Multi-Faceted Approach to Enhancing Inverter Longevity

EXTERNAL FACTORS

Grid Connection Failures

As the penetration of renewable energy sources continues to grow, it poses challenges to grid stability. Feedback from an onsite PV plant in Heilongjiang, China, highlights a significant issue where a majority of central inverters suffered damage due to the failure of Low Voltage Ride Through (LVRT) caused by grid short-circuits. In contrast, Huawei inverters equipped with a Smart PV Controller demonstrated exceptional performance by accurately identifying grid faults and ensuring stable operation following a successful LVRT procedure.

Huawei's Smart PV Controller is designed with robust grid-connected controllability, providing invaluable support for maintaining stable operations. Notably, this controller complies with China complex grid code, with the SUN 2000-150KTL-MG0 demonstrating its reliability.

Installation Error

Installation errors are not inherent to the product; they will nonetheless be discussed in Chapter 7.

ENVIRONMENTAL FACTORS

Temperature Fluctuations & Environmental Factors

Huawei's unique position as a pioneering inverter manufacturer with an extensive global distribution network and diverse clientele has provided invaluable insights into addressing the risk of lowered inverter longevity. With a presence in numerous countries and installations in a wide range of climatic conditions, Huawei has amassed extensive feedback and real-world experiences that serve as a rich source of knowledge and continuous improvement.

Huawei's ability to draw upon a wealth of global experiences and adapt its inverter technology accordingly sets it apart from many other manufacturers. Through this extensive reach, Huawei has garnered insights from diverse climates, spanning from extreme cold environments to scorching deserts, and everything in between. This unparalleled exposure to varied conditions has allowed Huawei to gain a deep understanding of the challenges and stressors that inverters may encounter in different regions and climates.

By analysing and applying these insights, Huawei has tailored its products to withstand the specific environmental challenges faced by its clients worldwide. This includes designing features and components that excel in extreme temperature ranges, resist corrosion in coastal regions, and remain resilient in the face of environmental factors like dust, humidity, and more.

The SUN2000 C&I inverters have shown stable operation in harsh environments. Several successful tests have been carried out such as the

A Multi-Faceted Approach to Enhancing Inverter Longevity

Low and high temperature storage and operation tests, the damp heat steady state test, and the salt spray test. It has successfully passed the tests according to the IEC 60068-2-1 standards, which is an international standard for the environmental testing of electrotechnical products. Furthermore, with an IP66 rating, it is well-protected against dust and water ingress. It is also worth mentioning again the SSCF-TECH present on the SUN2000-150KTL-MG0 and the SUN5000-150KTL-MG0 models which is designed to prevent the ingress of particles and to be self-cleaning.

Chapter 6 details the tests and the results of the SUN2000 C&I inverters.

Surge and Lightning Damage

Surge and lightning damage represent common and potentially catastrophic failures in inverters, posing a significant risk to their longevity and operational safety. Inverters are vulnerable to power surges or lightning strikes, which can lead to irreparable damage to their circuitry, potentially resulting in fires or explosions.

To address this critical issue, Huawei has established the Global Compliance & Testing Center (GCTC), a comprehensive laboratory facility with international recognition from authorities such as CNAS, ATLA, MET Labs, ITS, and CETECOM. Within this advanced testing facility, Huawei conducts rigorous assessments and experiments specifically focused on surge and lightning protection to ensure the reliability and resilience of its equipment.

These tests are designed to simulate and evaluate the performance of Huawei inverters under extreme surge and lightning conditions. By subjecting its products to these demanding scenarios, Huawei can identify vulnerabilities and weaknesses in the inverters' surge and lightning protection mechanisms. Subsequently, the manufacturer can refine its designs and implement enhanced protective measures to mitigate the risk of damage caused by surges and lightning strikes.

The table below recaps the most common sources of inverter failures and summarises the features and technologies included in the SUN2000 C&I inverters that address each of them, enhance the inverter's reliability and extend its lifetime.

Pic. 15.

RSD test setup

A Multi-Faceted Approach to Enhancing Inverter Longevity

Failure mode	Features of the SUN2000 C&I inverters / Actions on the SUN200 C&I inverters
Overheating	-Natural cooling method -Battery of tests) extreme high and low temperature trials ,temperature cycling assessment ,dust and humidity evaluation ,etc(-Rapid Shutdown) RSD(
Electrical component failures and ageing	-Smart String Level Disconnection) SSLD((-Smart Connector Temperature Detector) SCLD(-Careful testing and selection of components -Insulation Monitor Device) SmartIMD(
Communication failures	-PLC -Broadband MBUS chip
Isolation Faults	-MPPT-level isolation with high positioning accuracy -Smart Connector Level Detection) SCLD(
Grid connection failures	-Smart PV Controller -Experience on China grid
Installation errors	-Clear and comprehensive installation manual -Easy installation process
Environmental factors	-IEC tests in high and low temperatures ,high humidity and high salt spray environments -IP66 -Smart Self Clean Fan) SSCF-TECH(
Surge and lighting damage	-Performance evaluation under extreme surge and lighting conditions -Rapid Shutdown) RSD(

Conclusions and Key Insights

The SUN2000 C&I series of inverters address each of the major causes of inverter failure, enhancing its longevity. Huawei's unique and extensive global experience and continuous improvement efforts have enabled it to create a robust and reliable product that excels in various environments.

Huawei's innovative features and technologies minimise the risk of component-related failures, ensure stable communication, enhance isolation and fault detection mechanisms, and withstand challenging environmental conditions.

Huawei has established a comprehensive testing center where their inverter's performance has been verified through rigorous testing, reinforcing its reliability.

5. Manufacturing and Quality Assurance

Huawei's distinct competitive advantage lies in its high-quality products, which offer unparalleled adaptability to diverse geographical locations and climatic conditions, as previously discussed. Leveraging this extensive experiential database, the company has consistently pursued product enhancement initiatives.

Notably, a distinctive aspect of Huawei's operational ethos is its commitment to innovation and dedicated research and development endeavours, as previously discussed. This enduring commitment has enabled the assimilation of invaluable insights drawn from years of practical field experience, coupled with a manufacturing acumen, to meticulously refine both the manufacturing procedures and the end product.

While Huawei does engage external manufacturing partners for specific components, all of its products are produced in-house on its assembly lines. A culture of continuous enhancement in manufacturing quality and efficiency is deeply ingrained within Huawei's corporate culture, with employees actively encouraged and incentivised to propose improvements to the assembly process.

Pic. 16.

Huawei's factory

Additionally, the manufacturer boasts access to premium-grade, reliable components, which are judiciously integrated into its perpetually evolving inverter designs. We will elaborate on the testing of components used in the SUN2000 C&I series of inverters later on in this chapter.

Concurrently, Huawei's imperative to accommodate the high volume of demand for its products necessitates a high degree of automation within the manufacturing workflow. It is important to underscore that Huawei's scale of production would be unattainable without the optimisation and automation of the manufacturing process. This strategic emphasis on automation, complemented by rigorous quality assurance protocols and vigilant process monitoring, ensures the precise replication of its high-calibre designs. The next section develops Huawei's quality assurance.

The combination of utilising top-tier components, refined design methodologies, automation capabilities, and a stringent quality assurance framework, fortified by meticulous process oversight, results in exceptional product reliability. This multi-faceted approach, underpinned by extensive experience and commitment to quality and innovation, effectively increases the long-term reliability of its inverters and extends their operational longevity.

Quality Assurance Policy

Huawei's operational protocols align with globally recognised quality and environmental standards. Its adherence to ISO 9001:2015 and ISO 14001:2015 certification requirements underscores a comprehensive framework governing the manufacturing and supply of PV inverters.

ISO 9001:2015 stands as a pillar in ensuring the consistency of high-quality products. Its systematic approach meticulously regulates the entire manufacturing process. This, in turn, guarantees replicability of results and solidifies Huawei's commitment to maintaining high levels of quality assurance.

ISO 14001:2015, meanwhile, introduces an additional layer of significance by outlining prerequisites for an effective environmental management system. In practice, it equips Huawei with the tools to minimise environmental impacts throughout the product life cycle.

Testing Facilities


Pic. 17.

Barcode


Pic. 18.

Burn-In Test


Pic. 19.

Dielectric

The manufacturer's pursuit of quality is demonstrated through a global network of cutting-edge research laboratories. These facilities boast an impressive suite of environmental testing and simulation equipment, encompassing climatic, mechanical, wind, rain, irradiation, ice, dust, and corrosion assessments, tailored specifically for our inverters. The laboratories are also used to test products of third-party manufacturers as they seek Huawei's expertise for equipment testing. This underscores the industry's confidence in Huawei's standards.

Furthermore, the stringent reliability testing procedures applied to the SUN2000 products leave no room for conjecture. These tests are systematically conducted under standardised conditions, ensuring consistency and adherence to predefined requirements. Selection of qualification samples from production lots, all manufactured and tested through rigorously standardised processes, show Huawei's commitment to delivering top-tier quality and reliability. The following subsection presents the results of the tests performed in the laboratories on the components of the SUN2000 models.

Component Evaluation


Pic. 20.

Capacitor


Pic. 21.

Capacitors in power supplies


Pic. 22.

IGBT module


Pic. 23.

Inductor

In inverter technology, a precise understanding of component reliability is paramount to ensuring the long-term functionality of these critical devices. Certain components within inverters are more prone to early failure due to various factors, and among them, mechanical components such as fans, and most-used electrical components, including capacitors and photocouplers, stand out as the primary candidates with relatively shorter lifespans.

Capacitors, as essential energy storage components, serve a vital role in stabilising the electrical circuitry within inverters. They are responsible for filtering and regulating voltage, facilitating a smooth and consistent flow of

electrical power. However, capacitors are known to exhibit a finite operational life, primarily influenced by temperature variations and electrical stresses. Over time, these factors can lead to a decline in capacitance and an increase in internal resistance, ultimately culminating in capacitor failure.

Photocouplers, also known as optocouplers or optoisolators, are integral to electrical isolation and signal transmission within inverters. These optoelectronic devices play a critical role in safeguarding low-voltage control circuitry from high-voltage components. However, their performance is not immune to wear and ageing, particularly in scenarios involving frequent switching and high-frequency operations. This prolonged exposure to stressors can lead to a gradual deterioration of photocoupler functionality.

Fans, tasked with the crucial role of thermal management, are responsible for maintaining the inverter's internal temperature within specified operational limits. However, fans, by virtue of their mechanical nature and continuous operation, are intrinsically susceptible to wear and tear. Factors such as bearing wear, dust accumulation, and mechanical stress can contribute to fan failure. A malfunctioning fan can disrupt the cooling system, potentially resulting in overheating and a subsequent chain reaction of component failures.

To ensure the robustness and reliability of inverter components, Huawei employs a rigorous testing regime conducted within the confines of its dedicated laboratory facilities. These assessments involve subjecting critical components, including fans, capacitors, and photocouplers, to accelerated ageing simulations. By replicating extreme conditions and stressors, Huawei can evaluate the performance and durability of these components under challenging circumstances.

The outcomes of these assessments provide concrete data on component lifespan and inform continuous improvement efforts aimed at extending the longevity of inverter systems deployed in real-world scenarios. This commitment to thorough testing and quality assurance reinforces the reliability and bankability of Huawei's inverter technology in the field.

The table below presents the average results of the tests performed on a sample of fans from different manufacturers.

Component	Type	Average lifetime assessment result (years)
Fan	External fan	38.8
	Internal fan	57.4
	Dehumidifying fan	30.0

Manufacturing and Quality Assurance

The table below presents the results of the tests performed on a sample of capacitors from different manufacturers. For this component, two test methods were used to estimate the lifetime of the components: the ripple current test method[1] (Test method 1) and the temperature rise test method[2] (Test method 2). Both tests collectively contribute to predicting a capacitor's performance, reliability, and longevity in dynamic operational environments.

1 The ripple current test simulates real-world conditions on capacitors by applying high-frequency alternating currents with varying amplitudes, known as ripple currents. It assesses a capacitor's ability to withstand electrical stresses over extended periods, focusing on parameters like temperature rise and changes in capacitance and equivalent series resistance.
2 The temperature rise test measures a capacitor's thermal behavior when subjected to its rated voltage and current, ensuring it can dissipate heat efficiently.

Component	Type	Average lifetime assessment result (years)	
		Test method 1	Test method 2
Capacitor	Ox-foot capacitor	47.0	43.0
	Common lead type capacitor	63.2	59.1

Test results of lifetime assessment of capacitors of the SUN2000 C&I inverters

The table below presents the results of the tests performed on a sample of photocouplers from different manufacturers.

Component	Type	Average lifetime assessment result (years)
Photocoupler	CTR type	>100
	Threshold type 1	>100
	Threshold type 2	>100

Test results of lifetime assessment of photocouplers of the SUN2000 C&I inverters

Conclusions and Key Insights

Huawei's competitive advantage stems from its substantial production volume, providing extensive exposure to diverse locations and climates. This valuable experience drives continuous product enhancements. The company's commitment to innovation and research, coupled with practical field experience, refines manufacturing processes and end products.

High production demands necessitate automation, a key strategy. This, alongside stringent quality assurance protocols and vigilant monitoring, ensures precise replication of high-quality designs in Huawei's production lines.

Huawei's unwavering commitment to product quality and component reliability is demonstrated through its substantial investment in research laboratories.

Huawei's lifetime assessment and reliability tests confirm the company's meticulous selection of each component for the SUN2000 C&I inverters. These tests consistently demonstrate that the chosen components possess a projected lifetime exceeding 25 years. This dedication to quality ensures the long-term reliability and performance of Huawei's inverter technology.

Pic. 24.

Assembly line

6. Results of Product Testing

bsi.

Certificate of Registration

ENVIRONMENTAL MANAGEMENT SYSTEM - ISO 14001:2015

This is to certify that:

Huawei Technologies Duesseldorf GmbH
Hansaallee 205
Düsseldorf
40549
Germany

Holds Certificate No: **EMS 781918**

and operates an Environmental Management System which complies with the requirements of ISO 14001:2015 for the following scope:

The supply, installation, configuration, and commissioning of telecommunications equipment and associated professional and operational support services to both Utilities and ICT clients and enterprises.

Activities are related to IAF Sector 18.

For and on behalf of BSI:

David Fardel, Country Manager, Assurance - Continental Europe

Original Registration Date: 2011-09-21
Latest Revision Date: 2022-11-18

Effective Date: 2022-11-18
Expiry Date: 2023-09-20

Page: 1 of 4

ACCREDIA

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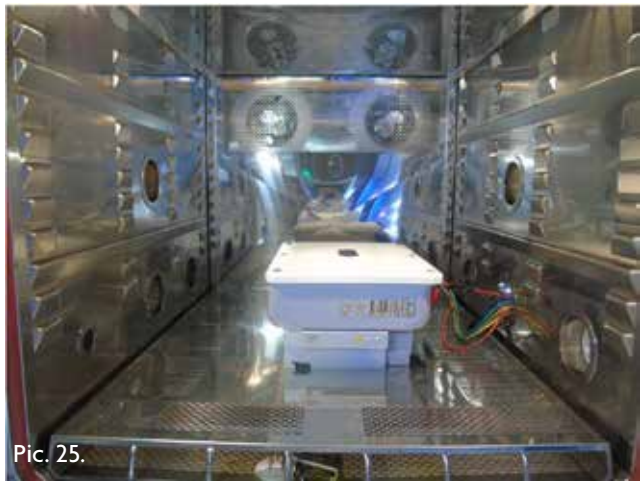
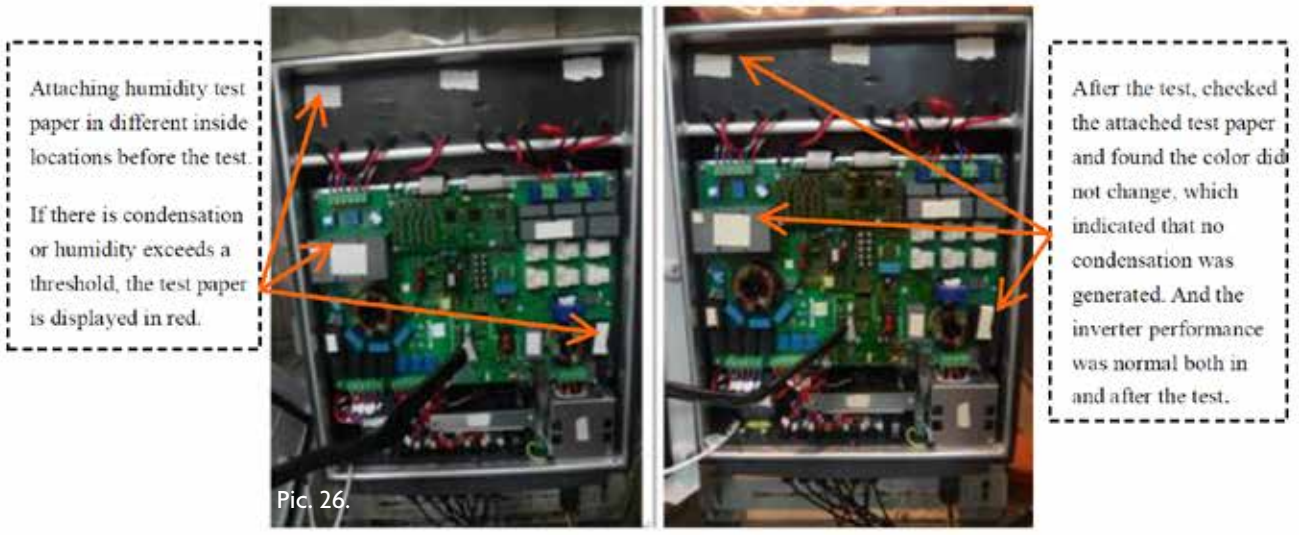
A Member of the BSI Group of Companies.



Pic. 25.

SUN2000-40KTL test setup



Pic. 26.

Comparison of Humidity test before and after the rain

The SUN2000 C&I series of inverters has undergone extensive testing inside of Huawei's facilities as well as by third-party experts.

Third-Party Certificates

We have reviewed the certificates issued by third-party experts. The following table briefly describes each one.

Certifying entity	Date	Product	Norm/standard	Description	Result
TÜV SUD	17/11/2022 22/09/2023	SUN2000-12-25KTL-M5 SUN2000-12-25KTL-MB0	EN/2019/ 50549-1 AC2019:	Technical requirements for the connection of generating plants up to an including type A/(1-1-) Type B (1-2-) which can operate in parallel with a public distribution network	Conform
Intertek	24/06/2022	SUN2000-12-25KTL-M5	IEC61727:2024 IEC62116:2014	IEC :61727 requirements for interconnection of PV systems to the utility distribution system IEC :62116 test procedure of the performance of islanding prevention measures used with utility-interconnected PV systems	Conform
TÜV SUD	03/11/2022 14/09/2022 20/07/2023	SUN2000-12-25KTL-M5 SUN2000-50KTL-M3 SUN2000-12-25KTL-MB0	DIN VDE0126-1-1:2023)With national deviation of France :DIN VDE0126-1-1VFR(2019	Compliance with the automatic disconnection device between a generator and the public low-voltage grid	Conform
TÜV SUD	29/07/2022 08/01/2021	SUN2000-12-25KTL-M5 SUN2000-30-40KTL-M3	EN+ 55011:2016 A1:2017 +A11:2020 EN+62920:2017 A11:2020 EN61000-6-1:2007 EN/61000-6-2:2005 AC2005: EN/61000-6-3:2007 A1:2011 /AC2012: IEC61000-6-3:2006 +A1:2010 EN61000-6-4:2007 +A1:2011 IEC61000-6-4:2006 +A1:2010 ETSI EN489-1 301 V2.2.3:2019 ,ETSI EN301 489-1V1.9.2:2011 ETSI EN489-17 301 V3.2.4:2020 EN61000-3-11:2000 EN61000-3-12:2011	Essential requirements of the Electromagnetic Compatibility Directive/2014/30) EU(	Conform

Results of Product Testing

Certifying entity	Date	Product	Norm/standard	Description	Result
Bureau Veritas	27/06/2023	SUN2000-30-40KTL-M3	EN50549-1:2019	Technical requirements for the connection of generating plants up to an including type A/(1-1-) Type B (1-2-) which can operate in parallel with a public LV distribution network	Conform
Bureau Veritas	22/02/2023	SUN2000-30-40KTL-M3	UTE C15-712-1:2013-07, ,0:2010-09+ ,2010-07:+ 1:2012-02+ DIN VDE0126-1-1:2013-08)VFR(2019 Ene-dis-PRO-RES10_E2020-06:	Requirements of PV installations connected to distribution public network Compliance with the automatic disconnection device between a generator and the public grid Description and study of decoupling protections for the connection of Generation Facilities connected to the public distribution grid	Conform
TÜV SUD	28/12/2020 23/11/2022	SUN2000-30-40KTL-M3 SUN2000-50KTL-M3 SUN2000-100KTL-M2 SUN2000-115KTL-M2	IEC62109-1:2010 IEC62109-2:2011	Safety requirements for the design and manufacture of power conversion equipment	Conform
Bureau Veritas	10/10/2022	SUN2000-50KTL-M3 SUN2000-100KTL-M2 SUN2000-115KTL-M2 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	IEC61727:2024 IEC62116:2014 IEC61727:2004	IEC :61727 requirements for interconnection of PV systems to the utility distribution system IEC :62116 test procedure of the performance of islanding prevention measures used with utility-interconnected PV systems	Conform
Intertek	18/10/2022	SUN2000-50KTL-M3	EN50549-1	Technical requirements for the connection of generating plants up to an including type A/(1-1-) Type B (1-2-) which can operate in parallel with a public distribution network	Conform
Dekra	23/12/2022	SUN2000-100KTL-M2 SUN2000-115KTL-M2	UTE C15-712-1:2013 / VFR 2019 DIN VDE0126-1-1:2013	Requirements of PV installations connected to distribution public network Compliance with the automatic disconnection device between a generator and the public grid Description and study of decoupling protections for the connection of Generation Facilities connected to the public distribution grid	Conform
Bureau Veritas	08/10/2022	SUN2000-100KTL-M2 SUN2000-115KTL-M2	EN + 55011:2016 A11:2020 EN + 62920:2017 A11:2020 EN IEC61000-6-3:2021 EN IEC61000-6-4:2019 EN61000-3-12:2011 EN IEC61000-3-11:2019 EN IEC61000-6-2:2019	Essential requirements of the Electromagnetic Compatibility Directive/2014/30) EU(	Conform

Certifying entity	Date	Product	Norm/standard	Description	Result
Dekra	08/06/2023	SUN2000-100KTL-M2 SUN2000-115KTL-M2 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	EN50549-1:2019	Technical requirements for the connection of generating plants up to an including type A/(1-1-) Type B (1-2-) which can operate in parallel with a public distribution network	Conform
Intertek	13/05/2024	SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	IEC/EN2010 :62109-1 IEC/EN2011 :62109-2	Safety of power converters for use in photovoltaic power systems	Conform
Intertek	11/05/2024	SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	EN+55011:2016 A2:2021 EN+62920:2017 A11:2020 EN+62920:2017 A1:2021 EN61000-6-3:2021 EN61000-6-1:2019 EN61000-6-4:2019 EN61000-6-2:2019 EN61000-3-11:2019 EN61000-3-12:2011	Essential requirements of the Electromagnetic Compatibility Directive/2014/30) EU(	Conform
Intertek	08/04/2024	SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	UTE C15-712-1:2013 DIN V VDE V0126-1-1:2013	Requirements of PV installations connected to distribution public network Compliance with the automatic disconnection device between a generator and the public grid Description and study of decoupling protections for the connection of Generation Facilities connected to the public distribution grid	Conform
Intertek	07/07/2023	SUN2000-12-25KTL-MB0	EN62109-1:2011 EN62109-2:2011 EN50385:2017 EN55385:2017 EN + 55011:2016 A1:2017+ A11:2020 + A2:2021 EN + 62920:2017 A11:2020 +A1:2021 ETSI EN 489-1 301 V1.9.2 (2011-09) ETSI EN 489-1 301 V2.2.3 52019-11(ETSI EN 489-17 301 V3.2.4 (2020-09) EN IEC61000-6-1:2019 EN IEC61000-6-2:2019 EN IEC61000-6-3:2021 EN IEC61000-6-4:2019 EN61000-3-11:2000 EN61000-3-12:2011 ETSI EN 328 300 V2.2.2 (2019-07)	Safety of power converters for use in photovoltaic power systems Essential requirements of the Electromagnetic Compatibility Directive/2014/30) EU(	Conform

Results of Product Testing

ATTESTATION

Product Service

Huawei Technologies Co., Ltd.

Administration Building, Headquarters of Huawei Technologies Co., Ltd., Bantian, Longgang District, Shenzhen, 518129, P.R.C

Product: Solar Inverter

Model: SUN2000-15KTL-M3, SUN2000-17KTL-M3, SUN2000-20KTL-M3, SUN2000-23KTL-M3, SUN2000-29.9KTL-M3, SUN2000-30KTL-M3, SUN2000-36KTL-M3, SUN2000-40KTL-M3

Parameters:
PV input operating voltage range: 200 V~1000 Vd.c.
The equipment complies with the requirements of standard
CISPR 11:2015+A1:2016/ EN55011:2016
CISPR 11:2015+A1:2016+A2:2019/EN 55011:2016+A1:2017
IEC 62920:2017/ EN 62920:2017
IEC 61000-6-1:2005/EN 61000-6-1:2007
IEC 61000-6-1:2016/EN IEC 61000-6-1:2019
IEC 61000-6-2:2005/EN 61000-6-2:2005
IEC 61000-6-2:2016/EN IEC 61000-6-2:2019
IEC 61000-6-3:2006+A1:2010/EN 61000-6-3:2007+A1:2011(Telecom Port)
IEC 61000-6-4:2006+A1:2010/EN 61000-6-4:2007+A1:2011(Telecom Port)
IEC 61000-6-4:2018/EN IEC 61000-6-4:2019(Telecom Port)
ETSI EN 301 489-1 V2.2.3:2019
ETSI EN 301 489-17 V3.2.4:2020
IEC 61000-3-11:2000/EN 61000-3-11:2000
IEC 61000-3-11:2017/EN IEC 61000-3-11:2019
IEC 61000-3-12:2011/EN 61000-3-12:2011

This attestation applies only to the particular sample of the product provided for testing.

Project No.:68.760.20.0930.01

Approved by:

Jessie He
EMC Department
Project Manager
Date: 2021-01-08
Page 1 of 1

TÜV SÜD Certification and Testing (China) Co., Ltd. Shenzhen Branch
Building 12&13, Zhineng Wisdomland Business Park, Nantou Checkpoint Road 2, Nanshan District, Shenzhen City, 518052, P.R. China

IEC Standards

We have also reviewed the reports of a series of tests produced in July 2022 by Huawei. The tests were made in accordance with IEC standards.

The following tests were performed. They are summarised in the table below.

#	Test Type	IEC Standard	Test conditions	Models	Result
1	Low temperature storage	IEC 60068-2-1:2007	-40°C; 24h	SUN2000-12-25KTL-M5 SUN2000-30-40KTL-M3 SUN2000-12-25KTL-MB0	**Pass**
2	High temperature storage	IEC 60068-2-2:2007	70°C; 24h	SUN2000-12-25KTL-M5 SUN2000-30-40KTL-M3 SUN2000-12-25KTL-MB0	**Pass**
3	Low temperature work	IEC 60068-2-1:2007	-25°C; 24h	SUN2000-12-25KTL-M5 SUN2000-50KTL-M3 SUN2000-30-40KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0 SUN2000-12-25KTL-MB0	**Pass**

#	Test Type	IEC Standard	Test conditions	Models	Result
4	High temperature work	IEC 60068-2-2:2007	40°C - 60°C; 24h	SUN2000-12-25KTL-M5 SUN2000-50KTL-M3 SUN2000-30-40KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0 SUN2000-12-25KTL-MB0	**Pass**
5	Temperature cycle test	IEC 60068-2-14:2009	-25°C to 60°C; 3h; 2 cycles	SUN2000-12-25KTL-M5 SUN2000-50KTL-M3 SUN2000-30-40KTL-M3 SUN2000-100KTL-M2 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0 SUN2000-12-25KTL-MB0	**Pass**
6	Damp heat cyclic (non operation)	IEC 60068-2-30:2005	25°C ~ 60°C; 50%RH ~ 95%RH; 24h; 2 cycles	SUN2000-115KTL-M2 SUN2000-50KTL-M3 SUN2000-30-40KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0 SUN2000-12-25KTL-MB0	**Pass**
7	Damp heat cyclic (operation)	IEC 60068-2-3:2005	95%RH; 60°C; 15h; 2 cycles	SUN2000-12-25KTL-M5 SUN2000-115KTL-M2 SUN2000-50KTL-M3 SUN2000-30-40KTL-M3 SUN2000-100KTL-M2 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0 SUN2000-12-25KTL-MB0	**Pass**
8	Constant humidity and heat test	IEC 60068-2-78:2012	60°C; 95%RH; 48h 60°C; 50%RH; 1h 25°C; 50%RH; 1h	SUN2000-12-25KTL-M5	**Pass**
9	High temperature and low pressure test	GB/T 2423.27--2020	60°C; 61.6kPa; 16h 40°C; 79.5kPa; 16h	SUN2000-12-25KTL-M5	**Pass**
10	Solar radiation test - 1	GB/T 2423.24-2013	25°C and 45°C; 1120*(1+/-10%) W/m² 8h solar radiation and 16h dark night; 3 cycles	SUN2000-12-25KTL-M5	**Pass**
11	Solar radiation test - 2	IEC 60068-2-5: 2018 Procedure Sa2	25°C and 40°C; 1090 W/m² Illumination T° 40°C, 20h; Dark T° 25°C, 4h 3 cycles	SUN2000-115KTL-M2 SUN2000-50KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	**Pass**
12	Solar radiation test - 3	IEC 60068-2-5: 2010 Procedure B	1120W/m² 40°C; 20h 25°C; 4h 3 cycles	SUN2000-40KTL-M3	**Pass**
13	Sine Vibration test	IEC 60068-2-6: 2007	5Hz ~200Hz	SUN2000-115KTL-M2 SUN2000-50KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0 SUN2000-12-25KTL-MB0	**Pass**
14	Random Vibration test	IEC 60068-2-64: 2019	5Hz ~10Hz; 10Hz ~ 50Hz; 50Hz ~ 100 Hz	SUN2000-115KTL-M2 SUN2000-50KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0 SUN2000-12-25KTL-MB0	**Pass**
15	Random Vibration with package	IEC 60068-2-64:2008	5Hz ~ 300Hz	SUN2000-12-25KTL-MB0	**Pass**
16	Bump with package	IEC 60068-2-27:2008	180m/s²; pulse width 6ms	SUN2000-12-25KTL-MB0	**Pass**
17	Mechanical shock test	IEC 60068-2-27: 2008	Half sinusoidal pulse; 50m/s²	SUN2000-115KTL-M2 SUN2000-50KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	**Pass**

Results of Product Testing

#	Test Type	IEC Standard	Test conditions	Models	Result
18	Low air pressure	IEC 60068-2-13: 2021	40°C; 55kPa; 24h	SUN2000-115KTL-M2 SUN2000-50KTL-M3 SUN2000-30-40KTL-M3 SUN2000-150KTL-MG0 SUN5000-150KTL-MG0	**Pass**
19	Constant temperature and humidity test (operation)	IEC 60068-2-78: 2012	60°C; 95%RH; 96h 25°C; 50%RH; At least 1h	SUN2000-50KTL-M3 SUN2000-30-40KTL-M3	**Pass**
20	Dry heat test	IEC 60068-2-2	60°C; 24h	SUN2000-100KTL-M2	**Pass**
21	Cold test	IEC 60068-2-1	-25°C; 24h	SUN2000-100KTL-M2	**Pass**
22	Drop with package	IEC 60068-2-31:2008	20kg - 30kg; drop height 0.5m	SUN2000-12-25KTL-MB0	**Pass**
23	Shock Operation (Non-Working)	IEC 60068-2-27:2008	100m/s²; pulse width 11ms	SUN2000-12-25KTL-MB0	**Pass**
24	Shock Operation (Working)	IEC 60068-2-27:2008	30m/s²; pulse width 11ms	SUN2000-12-25KTL-MB0	**Pass**
25	Compression and stacking with package	GB/T 4857,4-2008	28.9kg, 2h; 29.1kg, 2h	SUN2000-12-25KTL-MB0	**Pass**
26	Shock with package	IEC 60068-2-27:2008	300m/s²; pulse width 6ms	SUN2000-12-25KTL-MB0	**Pass**

IEC tests performed in Huawei's laboratory

For the inverter to pass these tests, it has to be shown that the connectors and components were not broken before, during and after the test and that the inverter operates normally, setting off no alarms.

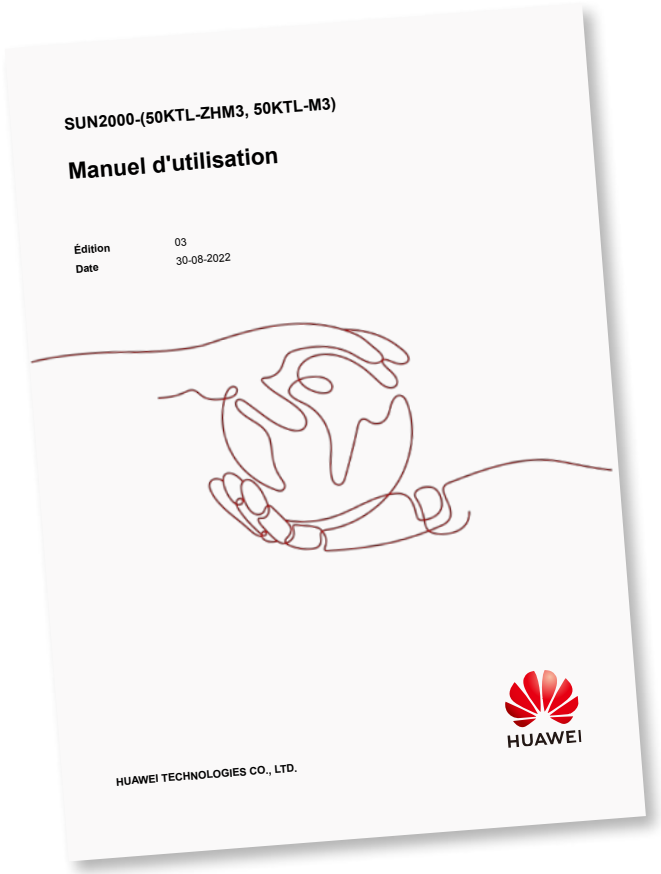
Conclusions and Key Insights

The SUN2000 C&I inverters have successfully undergone a rigorous battery of tests, encompassing evaluations conducted within Huawei's state-of-the-art advanced testing facilities as well as external third-party assessments.

7. Product Support

Pic. 27.

Installation



Installer Manual

In addition to the common failures listed earlier, installation errors represent one of the most common sources of inverter lifetime reduction. The installer manual serves as an invaluable resource by providing installers with clear, well-documented guidelines, safety information, and critical environmental considerations.

Huawei provides robust and comprehensive installer manuals to mitigate the risk of errors or defects during the installation phase of its inverters. This approach plays a pivotal role in extending the operational lifespan of these components.

Huawei's installer manuals serve as a repository of safety and technical information. From the initial installation to subsequent commissioning and troubleshooting, the manuals provide installers with meticulously outlined guidelines. These encompass installation prerequisites, detailed directions concerning personal, electrical, and mechanical safety protocols, and thorough insights into environmental prerequisites.

For example, the manuals place emphasis on environmental considerations. It offers guidance on the creation of well-ventilated environments, a crucial aspect for facilitating efficient heat dissipation around the inverter and subsequently mitigating the risk of overheating-related issues. Furthermore, the manuals strongly underscore the necessity of maintaining sufficient clearance around the inverter, discouraging the encroachment of vegetation, which could impede ventilation and jeopardise safety. The inclusion of detailed instructions, complemented by lucid visual aids, leaves no room for ambiguity, and substantially bolsters error prevention.

The manuals also dedicate attention to the preparatory steps required before installation. Huawei has provided a methodical preparation checklist to ensure that installers are adequately equipped and reduce the probability of improvisation during the installation process. This proactive approach further diminishes the chances of errors occurring.

Furthermore, Huawei offers explanations of all alarm codes and signals within the manual. This provision streamlines the installation and connection process, empowering installers to promptly identify and address any emerging issues.

Conclusions and Key Insights

Huawei's meticulous and comprehensive installer manual, combined with easily digestible documentation, constitutes a robust strategy to reduce the risk of errors during the installation phase. This proactive approach significantly enhances the overall reliability and longevity of its inverters, thereby positively impacting the efficacy and safety of photovoltaic systems.

About kiloWattsol

France's #1 Solar Expert

KiloWattsol has proudly held the position of France's foremost solar expert since 2007. Operating from our headquarters in Lyon, we have continuously provided unwavering support to industry-leading companies in the solar sector. As a trusted third-party partner for developers, financiers, and manufacturers, we leverage a strong foundation of scientific, technical, and business expertise to cater to our clients' requirements at every stage of their photovoltaic (PV) project life cycle. Whether it's financing, construction, operation, or M&A transactions, we are dedicated to serving our clients with excellence.

Pic. 28.

kiloWattsol site

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The following pictures are publicly available on the internet : Pic. 1 (page 2); Pic. 5 (page 18); Pic. 6 (page 18); Pic. 14 (page 26); Pic. 16 (page 30); Pic. 20 (page 32); Pic. 21 (page 32); Pic. 23 (page 32); Pic. 24 (page 35).

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