

SUN2000-330KTL-H2

Huawei String Inverter Technology Review (Reliability and Lifetime review)

Huawei Tech (UAE) FZ-LLC

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List of abbreviations

The following table lists some of the abbreviations used in this Report.

Abbreviation	Meaning
ac	alternating current
AFCI	Arc Fault Circuit Interruption
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
ALT	Accelerated Life Testing
BoP, BoS	Balance of Plant, Balance of System
CAPEX	Capital Expenditure
COD	Commercial Operation Date
CE	Conformité Européenne
CPI	Consumer Price Index
dc	direct current
DVT	Design Verification Testing
EIA	Environment Impact Assessment
EMI	Electromagnetic Interference
EPC	Engineering, Procurement, and Construction
ER	Employer's Requirements
ESD	Electrostatic Discharge
ESS	Energy Storage Systems
FAI	First Article Inspection
FIT	Feed-in Tariff
FMEA	Failure Mode Effects Analysis
FRT	Frequency Ride Through
GPS	Global Positioning System
HALT	Highly Accelerated Life Testing
HVRT	High-voltage ride-through
IBC	International Building Code
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IGBTs	Insulated-Gate Bipolar Transistors
IP	Intellectual Property
IP	Ingress Protection
IPD	Integrated Project Delivery
IQC	Incoming Quality Control
ISO	International Organization for Standardization
KPI(s)	Key Performance Indicators
LD	Liquidated Damages
LED	Light-emitting diode
LVRT	Low-voltage ride-through
MBUS	Meter-Bus
MES	Manufacturing Execution System
MOU	Memorandum of Understanding
MPPT	Maximum Power Point Tracking

Abbreviation	Meaning
MQE	Manufacturing Quality Engineer
MTBF	Mean Time Between Failure
NTP	Notice to Proceed
O&M	Operation and Maintenance
P&O	Perturb and Observe
PCB	Printed Circuit Boards
PDM	Product Data Management
PDT	Product Development Team
PID	Potential Induced Degradation
POD	Proof of Delivery
PPA	Power Purchase Agreement
PPC	Power Plant Controller
PV	Photovoltaic
RCD	Residual Current Detection
SCADA	Supervisory Control and Data Acquisition
SDV	System Design Verification
SEMS	Smart Energy Management Software
SIT	System Integration Testing
SoC	Statement of Compliance
SOC	State of Charge
SOP	Standard Operation Procedure
SPD	Surge Protection Devices
SSLD	Smart String Level Disconnection
TQC	Technical Quality Control
USB	Universal Serial Bus
VA, kVA, MVA	volt-amp (kilovolt-amp, megavolt-amp) – ac rating of (real and reactive) electrical power
VAR, kVAR, MVAR	volt-amp reactive (kilovolt-amp reactive, megavolt-amp reactive) – ac rating of reactive electrical power
VSI	Voltage Source Inverter
Wac, kWac, MWac	Watt ac (kilowatt ac, megawatt ac) – ac rating of real electrical power
Wp, kWp, MWp Wdc, kWdc, MWdc	Watt-peak (kilowatt peak, megawatt peak) – equivalent to dc electrical power rating of PV modules
WLAN	Wireless Local Area Network
ZVRT	Zero-voltage ride-through

1 INTRODUCTION

Huawei Tech (UAE) FZ-LLC ("the Customer") has contracted DNV AS Dubai Branch ("DNV") to perform an independent technology review of solar PV inverter model. This report (Report) presents the results of DNV's analysis.

Throughout this report, comments have been made that should be reviewed in detail indicating the views of DNV on key areas of product design and performance. The comments herein resulted after reviewing extensive documentation presented by Huawei, interviewing key personnel, and performing a manufacturing review at the Huawei factory in China.

1.1 Executive Summary

Huawei, established in 1987 and headquartered in Shenzhen, China, is a global leader in Information and Communications Technology (ICT) devices with operations in more than 170 countries and a workforce exceeding 200,000. While historically focused on telecommunications and consumer electronics, the company has expanded into digital power and PV solutions since 2013, building more than a decade of experience in the manufacturing, and deployment of PV inverters solutions. The SUN2000 inverter portfolio (first generation deployed in 2018), is one of Huawei's core offerings, now in its fourth generation and widely deployed across utility-scale solar projects. Financially, Huawei remains a strong and stable supplier. The company consistently allocates more than 20% of revenue to research and development, reinforcing its innovation leadership in AI, digital platforms, and renewable integration.

The model SUN2000-330KTL-H2, is a three-phase, transformerless string inverter designed for 1,500 V DC PV plants. It delivers up to 330 kW of AC output with a peak efficiency above 99% and a European efficiency of 98.8%, supported by advanced features such as Smart IV curve diagnosis, Arc Fault Circuit Interruption (AFCI), Potential Induced Degradation (PID) recovery, and string-level monitoring. Its IP66 protection, smart air cooling, and wide operating temperature range (-30 °C to +60 °C) ensure reliable operation in harsh hotter climatic conditions. Huawei has a strong track record in the PV string inverter solutions, with many common components and methods used across solar inverters. DNV views positively the features of the inverter and the standards followed for the design and testing of the inverter.

Huawei's manufacturing process is supported by a string quality assurance framework, including Incoming Quality Control (IQC), automated Printed Circuit Board (PCB) assembly, optical and X-ray inspections, and environmental stress testing. Huawei's own manufacturing plant is certified under ISO 9001 (Quality), ISO 14001 (Environmental), and ISO 45001 (Occupational Health & Safety), supporting product reliability, traceability, and alignment with internationally recognized management system standards. DNV finds the overall manufacturing process to be consistent with manufacturers in the solar inverter industry and found to be controlled by engineering released procedures and methods.

The SUN2000 series complies with key international standards, including IEC 62109 (safety), IEC 62116 (anti-islanding), IEC 61727 (grid interface), and IEC 61000 (EMC). For GCC deployment, Huawei also supports certification to local grid codes. While CE marking is not mandatory in the Middle East region, it is often accepted as supporting evidence of conformity.

Huawei has performed environmental adaptability testing, HALT, and durability testing of the inverters before commercial production. Overall, the product reliability testing demonstrates Huawei's systematic approach to accelerated reliability verification. The test methodology effectively identifies design vulnerabilities early in the product development cycle, supporting continuous improvement in thermal, mechanical, and electronic durability

Huawei states that the target design life for their PV solar string inverter products is 25 years, and components are specified and verified through testing to meet this requirement. Huawei provided detailed results of their calculations and testing to DNV for review to gain an understanding of the inverter life. The accelerated tests performed by Huawei were

intended to statistically support an inverter design life of greater than 25 years, with end-of-life due to component wear-out, or due to the accumulation of steady-state failures. DNV finds that the Huawei accelerated test program provides meaningful data regarding inverter life.

Huawei does not anticipate any accelerating failure rates within a 20-year useful life period and marks the end of useful life to occur when the annual failure rate reaches 10%. In order to support a life projection of up to 20 years of useful life, DNV recommends thermally accelerated life testing where the hours under test greatly exceed the expected product life, on an accelerated basis. DNV also recommends a test to failure, with a sample size large enough to rule out low occurrence defects. DNV is of the opinion that these enhanced accelerated testing requirements must be applied where extensive field performance data for the model under review are not available.

DNV acknowledges the long-term efforts of Huawei to refine the inverter design process, and the testing for reliability. DNV recommends providing more supporting field data for the models under review, and/or extensive inverter accelerated test data demonstrating a long product life. Extensive accelerated test data would include a large group of inverters operated for an accelerated period of greater than 25 years. As of the date of this report, the number of inverters model SUN2000-330KTL installed appears to be adequate to significantly diminish the likelihood of premature failures due to varying site conditions.

DNV notes that if workshop repairs (provided by Huawei in some markets) are accounted then the useful life can be extended up to 25+ years.

This report details the various DNV findings related to the Huawei inverter.

1.2 Scope of review

The scope of work for the review was defined in the Proposal [1], dated 10th March 2024. DNV prepared this independent review of Huawei three-phase string inverter series to communicate product details, manufacturing details, performance details, quality and reliability details, and Huawei's expected inverter useful life details. High reliability and long life of photovoltaic (PV) inverters are critical for the successful operation of PV power plants. Modern solar PV power plants are expected to operate for 25 years or more. Inverter durability has historically been an issue impacting PV system availability, maintenance cost, and energy production. Dependability and useful life are important considerations for PV inverter customers when selecting an inverter supplier and model.

This review covers Huawei's SUN2000 1500 Vdc transformerless string inverters for the Middle East market. The models include the 1500 Vdc SUN2000-330KTL-H2 three phase string inverters.

The primary objective of this Report is to assess factors that would affect the product's performance and reliability in the field and Huawei's ability to deliver and service the products. Such factors will include the design, quality of materials, product performance, regulatory compliance, reliability tests, and the manufacturing and quality control processes.

1.3 Methodology

In general, this Report contains information that would be included in an Independent Engineering review intended for financial institutions, customers, and project developers. DNV is uniquely qualified to conduct this study due to its extensive background and experience in solar independent engineering and technology due diligence work.

To facilitate assessments in some of these areas DNV visited the Huawei factory in China.

For this report information was aggregated from multiple Huawei sources and provided to DNV for generation of this report by:

- Dr. Appala Naidu Talada, Regional Technical Solutions Manager
- Mr. Wangpeng, Director for Smart PV solutions, ME&CA

1.4 Assumptions

This Report summarizes DNV's assessment of the SUN2000-330KTL-H2 and relies on the accuracy of the information provided by Huawei. Huawei has been responsive and thorough in providing the data that DNV has requested.

This Report is based on some information not within the control of DNV. DNV believes that the information provided by others is true and correct and reasonable for the purposes of this Report. DNV has not been requested to make an independent analysis or verification of the validity of such information. DNV does not guarantee the accuracy of the data, information, or opinions provided by others.

In preparing this Report and the opinions presented herein, DNV has made certain assumptions with respect to conditions that may exist, or events that may occur in the future. DNV believes that these assumptions are reasonable for purposes of this Report, but actual events or conditions may cause results to differ materially from forward-looking statement.

2 COMPANY EVALUATION

2.1 General Business

Huawei is a multinational company which was founded in 1987 and began manufacturing ICT electronic devices in high volume in 2004. As a large, employee-owned ICT company; Huawei has subsidiaries in over 170 countries and more than 207,000 employees. The company headquarters is located in Shenzhen, China. The diagram displayed in Figure 2-3 shows the company's highlights.



Figure 2-1 Huawei's Global Team [2]

The overall global inverter market summary is attached in Figure 2-2 below.

Huawei Smart PV: Leading the Global Inverter Market for 10 Consecutive Years and Building Multiple Global Benchmark Projects

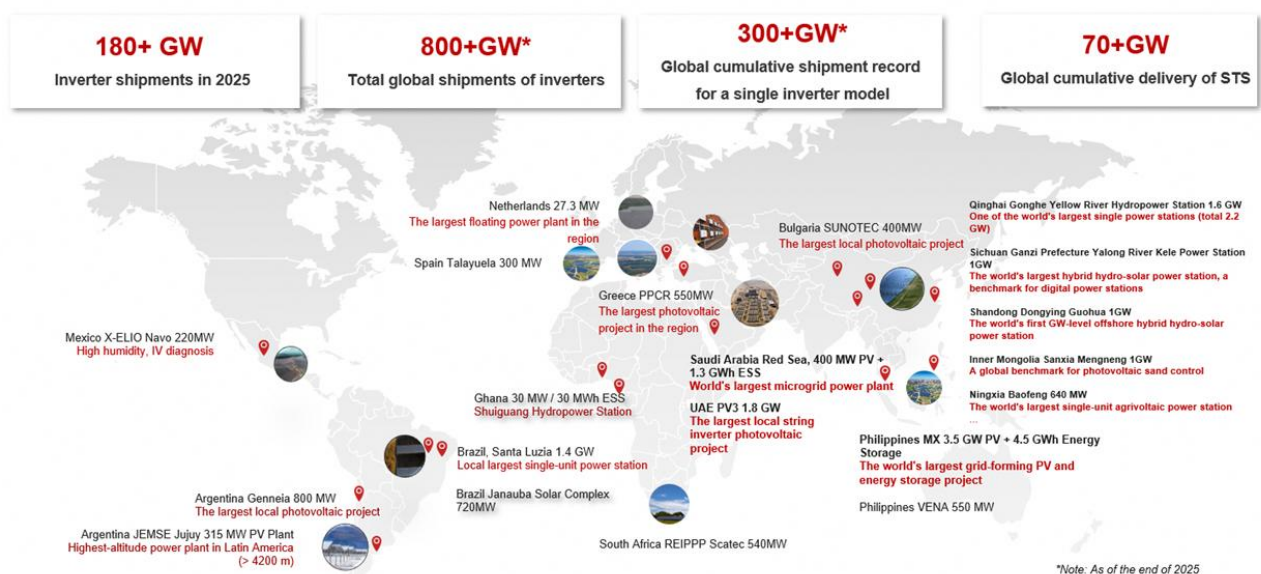


Figure 2-2 Global Inverter Market – Huawei [2]

2.2 Product History

Huawei's portfolio spans a wide range of industries, including telecom and networking equipment such as 5G infrastructure, consumer electronics like smartphones and smart devices, semiconductor design through its HiSilicon subsidiary, and software platforms like HarmonyOS. The company is also active in cloud computing, AI chips, solar technology, electric vehicle systems, and various industrial solutions. Figure 2-3 shows the diverse core business areas.

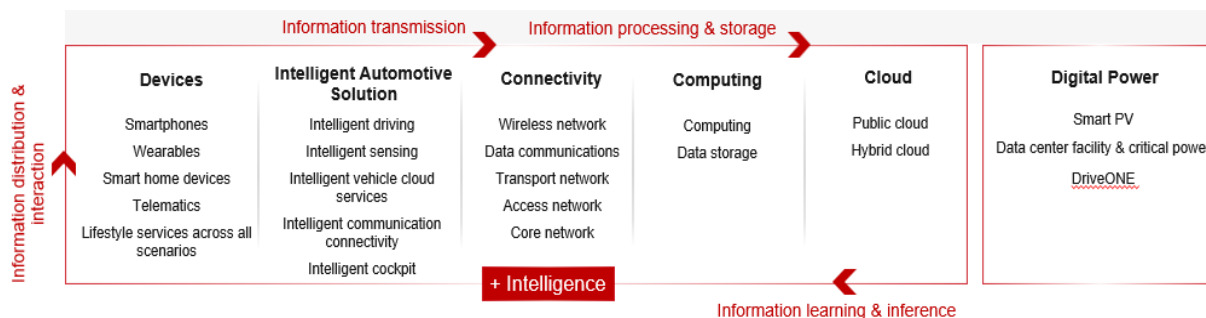


Figure 2-3 Huawei's Core Business Areas [2]

Within Digital Power Smart PV, the Huawei SUN2000 series solar inverters examined in this report have the following history showed in Table 2-1 & Figure 2-4.

Table 2-1 Huawei SUN2000 series product history [6].

Generation	Representative Models	Key Features
1st – Early String Inverters (2012–2015)	SUN2000-8KTL, 12KTL, etc.	Max efficiency ~98.5%, 2 MPPTs, integrated DC switch, RCMU, IP65, RS485/USB, Type II surge arresters, fuse-free, natural cooling.
2nd – Mid to High-Voltage String Inverters (2018–2019)	SUN2000-8/10/.../20KTL-M2	AI-powered arc-fault protection, optimizers support, efficiency up to ~98.65%, 1,080 V DC, dual MPPT, natural cooling, WLAN/Ethernet/4G.
3rd – Residential Hybrid / C&I (2020–2021)	SUN2000-3/.../10KTL-M1 (three-phase)	Hybrid-ready with AFCI active arcing protection, up to 30% more energy with optimizers, battery interface, three-phase output, RS485/Wi-Fi/4G.
	SUN2000-8/10K-LC0 (Single-phase)	Battery ready, plug-and-play whole-house backup, active arcing protection, up to 98.1% efficiency.
	SUN2000-5/6/8/10/12K-MAP0 (Three-phase newer)	AFCI & RSD, connector temp detection, asymmetric load, future-ready with LUNA S0/S1, whole-home backup, up to 98.6% efficiency.
4th – High-Power Utility-Scale (2022–2023)	SUN2000-330KTL-H1	Max eff ≥99%, EU eff ≥98.8%, 1,500 V DC, 6 MPPTs, SSLD, SCLD, Smart IV diagnostics, self-cleaning, IP66.

10 + Years Leading Industrial Innovation

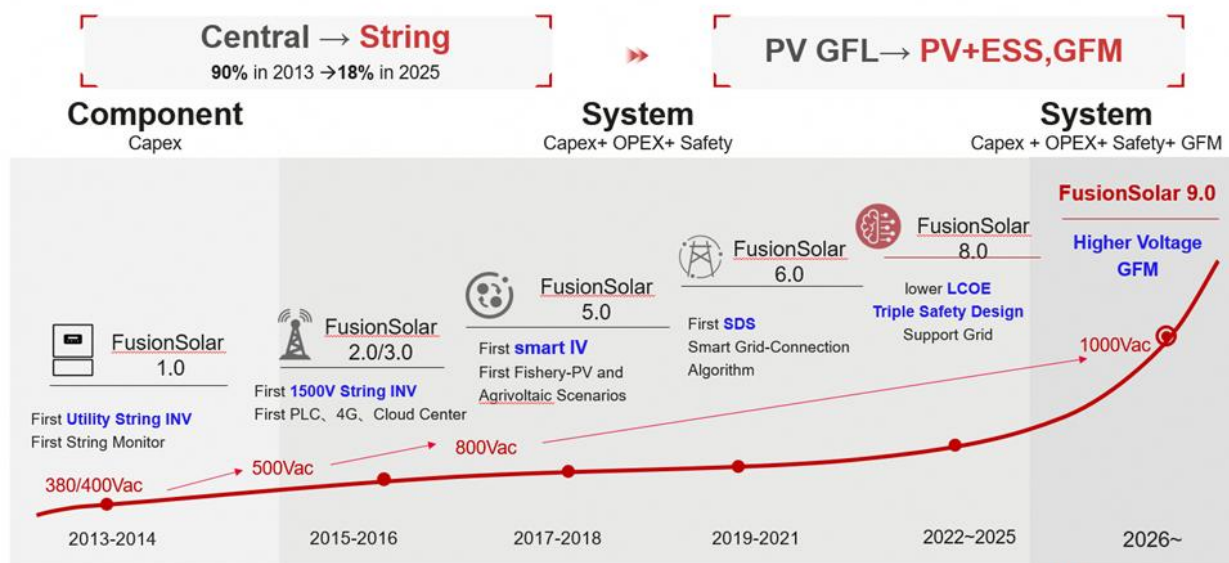


Figure 2-4 Evolution of Fusion Series Solar String Inverter

The current analysis focuses on the fourth generation of Huawei SUN2000 inverters, which is characterized by the following specific features [6]:

- Product type: Three-phase grid-tied PV string inverters.
- Function: Convert DC power from PV strings into AC power and feed it into the grid.
- Models covered: SUN2000-300KTL-H0, SUN2000-280KTL-H0, SUN2000-330KTL-H1, SUN2000-330KTL-H2, SUN2000-250KTL-H3, SUN2000-250KTL-H1, SUN2000-275KTL-H1.
- Rated output power: 250 kW to 300 kW (depending on model).
- Efficiency: 98%.
- Self-consumption at night (sleep mode): 4.8 W.
- Weight: 112 kg (including 8 kg packaging).
- Dimensions (W × H × D): 1048 × 732 × 395 mm.

DNV concludes that while there are notable design advancements in the fourth-generation SUN2000 series, its development builds on Huawei's extensive manufacturing expertise and the proven field performance of earlier SUN2000 generations, providing confidence in its long-term reliability and operational success.

2.3 Company Financials

DNV has been provided with the financial main KPI's (Key Performance Indicators) of the years 2020, 2021, 2022 and 2024 [3] that summarized the financial health of the company over the mentioned periods. For the years provided, Huawei income statement shows a decrease from 2021 to 2022 and an increase from 2022 to 2024.

Table 2-2 Huawei's Revenues & Profits [3]

Year	Revenue (USD billion)	Net Profit (USD billion)
2020	136.72	9.92
2021	99.89	17.84
2022	92.34	5.11
2023	99.45	12.28
2024	118.16	8.58
2025	126.02	9.73

Based on the latest global solar inverter market share study issued by Wood Mackenzie [4] Huawei's inverter shipments in 2025 represented a considerable share of the global market (Figure 2-5). Over the past five years, Huawei has consistently ranked as the leading supplier by market share and remains by far the largest supplier of string inverters globally.

Global PV inverter market share rankings by shipments, 2025

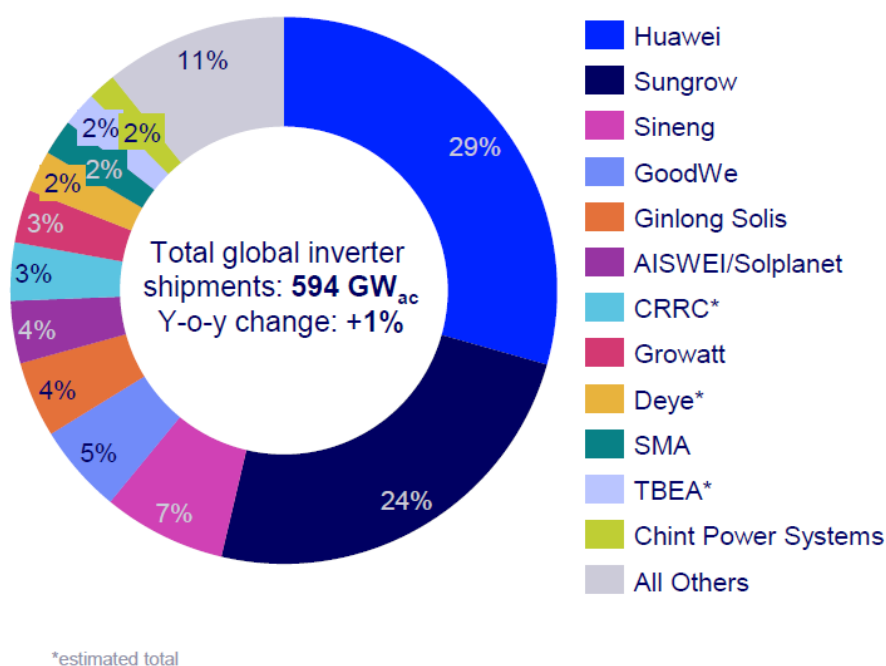


Figure 2-5 Global PV inverter shipments, 2025 (GWac) [4].

From Huawei's 2024 annual report [3], here's a direct summary of the strategies and measurable targets for the coming years:

- Sustain high R&D investment by allocating over 20% of its annual sales revenue each year, focusing on foundational AI and computing technologies, HarmonyOS, Kunpeng, Ascend, and cloud computing.
- Over the next three years, Huawei will build "reserve teams" for AI, computing, and cloud markets.
- Advance renewable integration into grids with smart Energy Storage Systems (ESS) platforms while promoting carbon reduction, energy efficiency, and circular economy initiatives.

DNV finds these strategies in line with the expected global inverter market tendency.

2.4 Intellectual property (IP) evaluation

Huawei's approach to intellectual property (IP) rights is based on a commitment to innovation, protecting its own IP, and respecting that of others. Huawei engages in cross-licensing to share its technology and receive fair compensation and participates in open standards to contribute to industry-wide advancements [7].

Huawei has one of the largest patent portfolios in the world. As per Huawei's 2024 annual report [3] there are total 150,000+ active granted patents in the Company's name. Huawei has also shared list of 59 patents and their corresponding certificates that are in direct relation with the product technology. Huawei reports to DNV that competitor's patent activities are continuously monitored and, when required, active countermeasures are implemented to mitigate risk. Although the solar industry historically has not been particularly litigious regarding intellectual property, DNV views the proactive IP strategy of Huawei positively [8][9].

3 MANUFACTURING EVALUATION

3.1 Manufacturing Locations

Huawei maintains a manufacturing foundation with one major owned facility dedicated to inverter production, complemented by multiple contract manufacturing partners across Dongguan and Huizhou. The total built-up area across all listed facilities exceeds 29 hectares, with a declared production capacity of 200,000 MW/year at the core Huawei facilities (including contract manufacturer). While product details for contract manufacturers are not fully disclosed, their involvement indicates a flexible and scalable production model suitable for large-scale deployment in the renewable energy sector. DNV notes that, in the event contract manufacturing is deployed for the Project, compliance with all applicable IEC and ISO certifications should be verified as part of the project-specific evaluation. As part of the current review, only Huawei's own manufacturing facility was visited, and the applicable certifications were verified for that facility.

Based on the information received from Huawei [16], here is the manufacturing facilities overview presented in Table 3-1

Table 3-1 Manufacturing facilities overview

Factory Name	Location	Built-up Area (Hectares)	Facility Type	Capacity
Huawei South Factory	Dongguan City, Guangdong Province, China	11.15	Own Factory	200,000 MW/Year
Dongguan Yangtian Electronic Technology Co., Ltd.	Dongguan City, Guangdong Province, China	5.25	Contract Manufacturer	
Jiancheng Hengrui (Huizhou) Electronics Co., Ltd.	Huizhou City, Guangdong Province, China	5.85	Contract Manufacturer	
Lucky Harvest Co., Ltd.	Dongguan City, Guangdong Province, China	6.75	Contract Manufacturer	

3.2 Factory Inspection

As part of this technology evaluation, DNV visited Huawei's inverter manufacturing location on 20 Nov 2025 to perform a factory inspection. Huawei representatives from the procurement, production, and quality departments etc. participated the factory inspection. The key participants for the inspection are listed in Table 3-2. The inspected factory is located at Huawei South Factory D Zone, East Gongye Road, Dongguan, Guangdong, China. Huawei used this location to manufacture PV inverters since 2014. A sketch map of the whole factory zone is shown below in Figure 3-1. The whole factory zone is used for manufacture inverters, energy storage system, charging piles and consumption products.

The whole factory zone in Dongguan is divided into four areas totaling around 1.4 km². Area B is around 519,000 m² including B1 and B2 zones. The areas of C&D are around 734,000 m². The whole Dongguan facility has over 20,000 employees.

DNV inspected the inverters workshop shown in Figure 3-2. The information and technical insights obtained by DNV during this factory visit have been integrated into the relevant sections of this report.

Table 3-2 Huawei factory inspection participants

Name	Company	Title
Jun Lu	DNV	Team Lead – Solar, Renewables China
Appala Naidu Talada	Huawei	Technical Solutions Manager
Jian Luo	Huawei	Customer Quality Engineer
Xianmin Li	Huawei	Production Operator

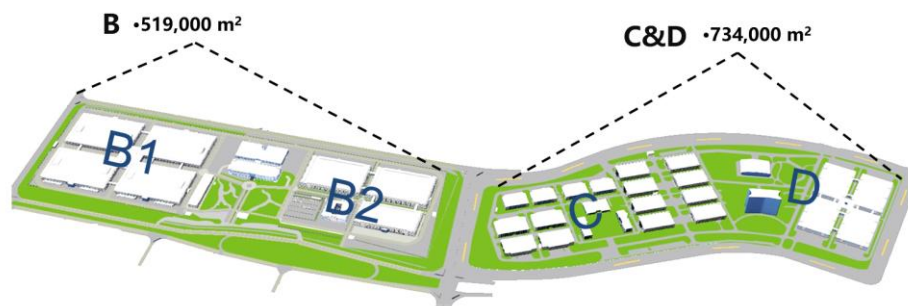


Figure 3-1 Sketch map of the factory

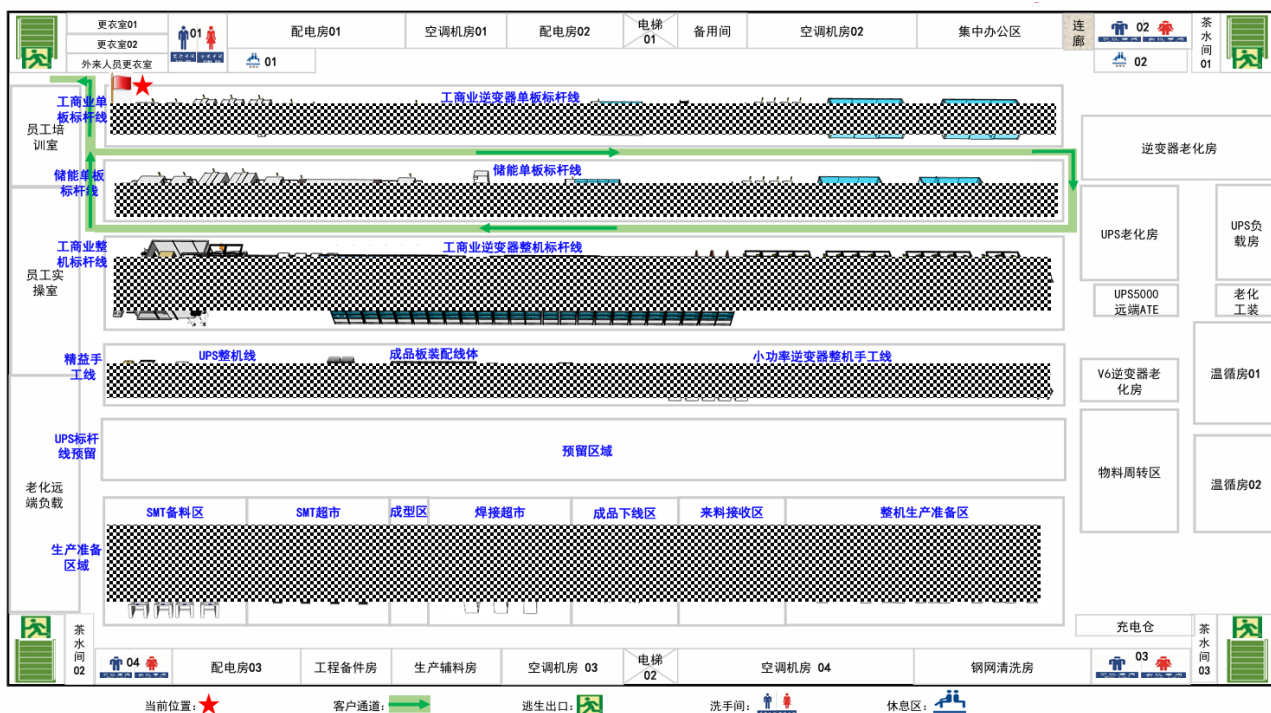


Figure 3-2 The inspected inverters factory workshop layout (manufacturing plant floor plan)

3.3 Manufacturing Process

The production of a solar inverter, such as the Huawei SUN2000 series, is carried out through a controlled and systematic sequence of manufacturing steps, each designed to ensure high electrical efficiency, robust mechanical integrity, and reliable performance throughout the product's operational life.

DNV observed that the workshop is accessible with all manufacturing areas clearly delineated and established each process. The facility employs automated equipment across multiple areas to support manufacturing operations and enhance consistency in the assembly process. Per work order, materials are kitted from the incoming material warehouse to ensure all necessary components are available at each assembly station. Floor stock items are systematically organized and clearly labeled. DNV observed that each station is equipped with prominent signage and clearly displayed assembly procedures. The assembly instructions reviewed by DNV were found to contain a sufficient level of detail..

It is worth to emphasised that all of assembly prcedures data are stored in the MES system. Huawei names the system MES+, which means all of the production data are controlled by the system. Furthermore, Huawei is training AI to monitor critical manufacturing process for consumption products. The same AI technology will be implemented into all

the production processes of inverters later. Currently, the critical processes are monitored by cameras as Figure 3-3. The data will be stored in the MES+ system.

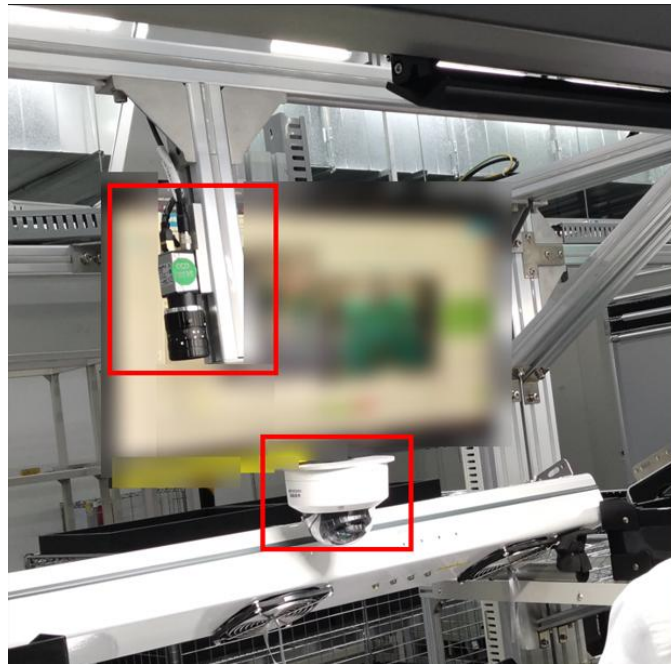


Figure 3-3 The cameras for critical points

Manufacturing area is divided into two distinct work areas to optimize production processes and material flow . The second floor is utilized for inverter PCB assembly, while the first floor is for inverter assembly and test. Almost all the transportation is done by Automated Guided Vehicle (AGV) as shown in Figure 3-4.

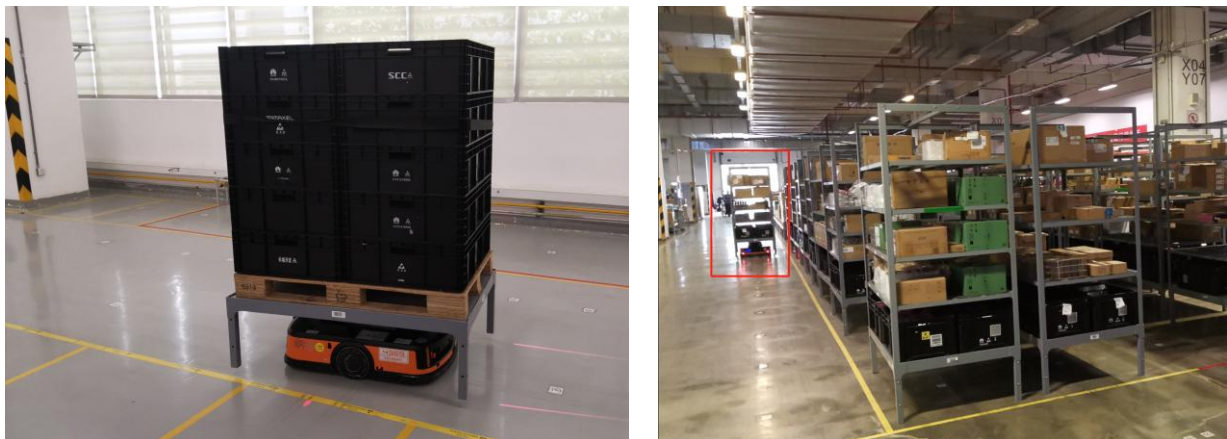


Figure 3-4 AGV for transportation within the factory

Incoming materials are selected from Huawei central warehouse. The central warehouse is used for all of Huawei products produced in the whole factory zones. The central warehouse runs automatically with only a few persons as Figure 3-5. The finished products will be transported to a product warehouse around 50 minutes away from the inspected factory by car, which DNV did not inspect due to limited inspection period.



Figure 3-5 Central warehouse for incoming materials

3.4 Quality System Overview

Production begins with the procurement of certified components, such as insulated-gate bipolar transistors (IGBTs), control boards, passive magnetic devices, and corrosion-resistant enclosures, which are verified against design specifications through incoming quality control.

The Incoming Quality Control (IQC) process for new material batches at Huawei begins with the receipt of goods and an initial verification of associated documentation within the Product Data Management (PDM) system or linked databases. If required information is missing, the Technical Quality Control (TQC) team is engaged to provide datasheets and any special requirement documents before inspection proceeds. The process then moves into a detailed physical assessment of the material to confirm compliance with specifications. Conforming items are approved through a First Article Inspection (FAI) report and transferred to storage. Non-conforming items trigger the IQC Non-Conformance Management phase, where the Manufacturing Quality Engineer (MQE) validates documentation accuracy and determines whether identified issues can be resolved internally. If corrective action is acceptable, responsibility is assigned to the relevant owner; otherwise, the material is returned to the supplier. This structured workflow ensures traceable decision-making, maintains product quality standards, and minimizes the risk of defective components entering production. Figure 3-6 shows the process detailed above.

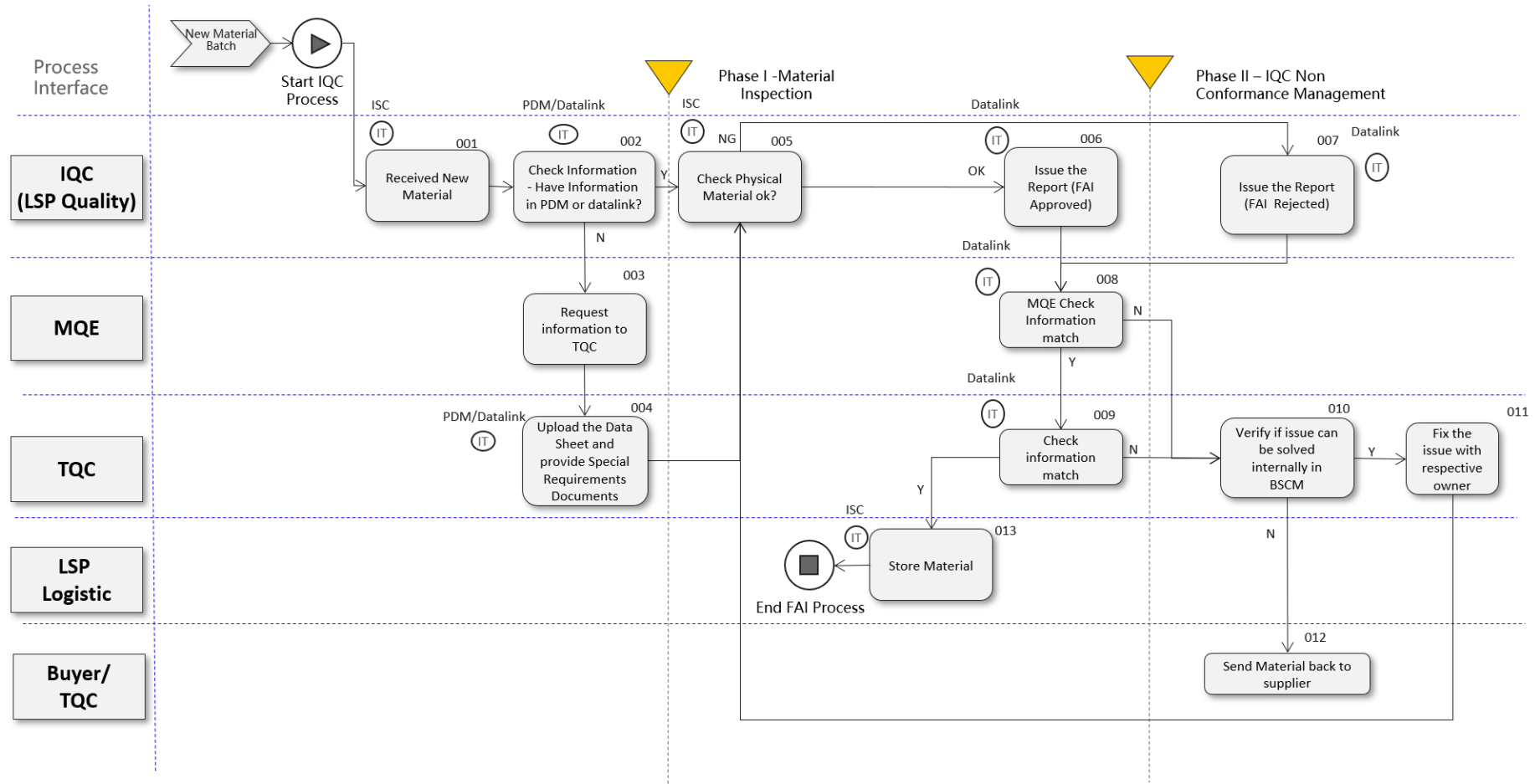


Figure 3-6 Incoming Quality Control Process for new materials at Huawei [10]

After this PCBs are populated using automated surface-mount and through-hole assembly techniques, with optical and X-ray inspections confirming assembly integrity. These boards are then integrated into power modules applying thermal management solutions and mounting them into weather-sealed enclosures. Firmware is uploaded to govern conversion algorithms and protection functions, followed by calibration to ensure accurate power tracking and grid compliance. Each unit is subjected to electrical performance testing, protective function verification, and safety compliance checks, with representative samples undergoing environmental stress testing to validate performance under extreme conditions. Final inspection covers both technical and cosmetic criteria before packaging and distribution.

This structured manufacturing approach, consistent with practices outlined in IEC 62109 and IEC 61727 standards, supports the high efficiency and operational reliability associated with the SUN2000 product family.

Additionally, Huawei's manufacturing operations (Huawei South Factory) are certified under internationally recognized systems:

- ISO 9001: 2015 Quality Management System [13]
- ISO 14001: 2015 Environmental Management System [14]
- ISO 45001: 2018 Occupational Health and Safety Management Systems [15]

During the factory visit period, DNV found quality issues discovered during the production process are handled in accordance with the "Production Quality Issue Handling Procedure". The person who discovers the issue shall raise their hand to provide feedback and fill out the production quality issue form for handling. At the same time, non-conforming products will be marked and isolated and stored in the designated non-conforming product area. Furthermore, DNV highlights all of the procedures are operated online and the defect data will be stored into MES+ system as Figure 3-8.



Figure 3-7 Non-conforming inverter PCB and inverter storage area and defective product identification card



Figure 3-8 On-line defect entry

Product traceability records are applied for all components used throughout the entire manufacturing processes. The whole system is composed of three main sub-systems. MES+ is for data of production process; WMS is for data of warehouse and ISC is for logistics. DNV checked the traceability records during the factory visit period. The whole system is working well. It is worth to emphasis that GPS is used for logistics, and then the location of a product can be easily found during transportation.

Huawei maintains a list of all tooling and measuring equipment together with its serial number, calibration status and certificate, and its validity date. DNV observed Huawei's use properly maintained tooling and instruments during the manufacturing processes.



Figure 3-9 Calibration for safety regulation tester

3.5 Supply Chain Management

DNV reviewed description of supply chain management provided by Huawei, in which Huawei recognizes and emphasizes the sustainability of management of the supply chain. Common supplier management is also mentioned in the document such as new supplier certification, routine supplier management and supplier performance management.

A brief description of boarding of suppliers is provided including issuance and collection of supplier certification documents, supplier qualification matching, on-site assessment, sample certification and comprehensive supplier evaluation.

Internally, Huawei uses the MES+ computer-based software platform to track all suppliers, materials, and orders. As soon as a sales order is received and entered, the system automatically triggers demand for each component and supplier based on the latest revision of the manufacturing bill of materials. Suppliers and suppliers' material are routinely and proactively monitored for quality control.

DNV inspected the process of the supply chain management system. A part of on-line processes from the system are provided in **Figure 3-10** General Procurement Supplier Qualification Process and **Figure 3-11** General Procurement Supplier Performance Process.

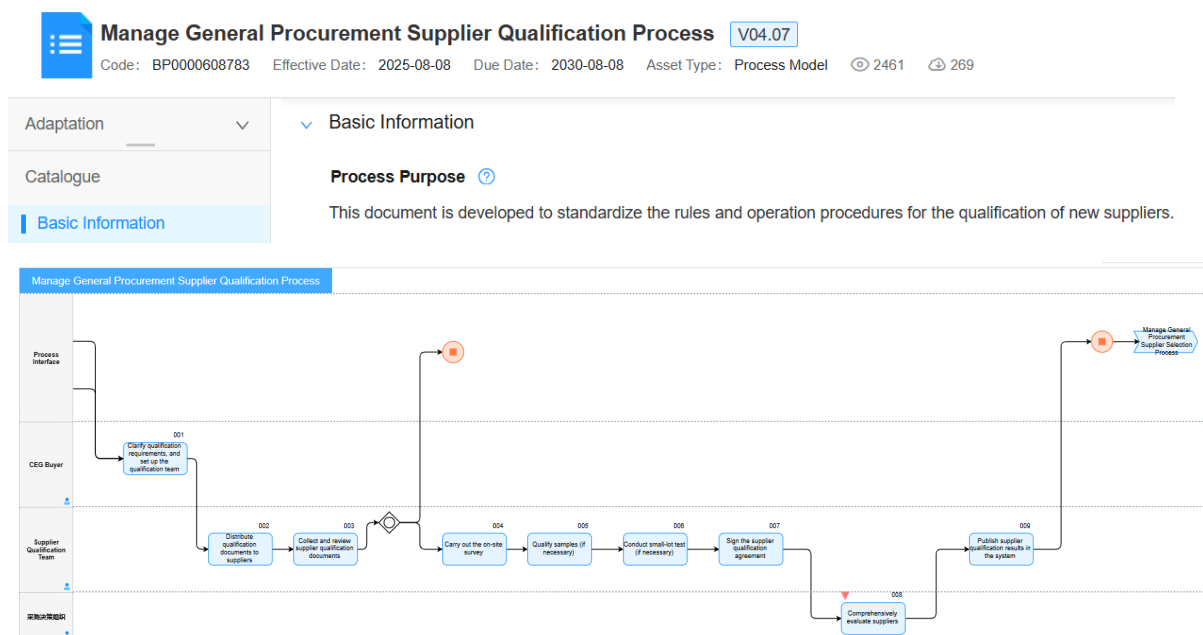


Figure 3-10 General Procurement Supplier Qualification Process

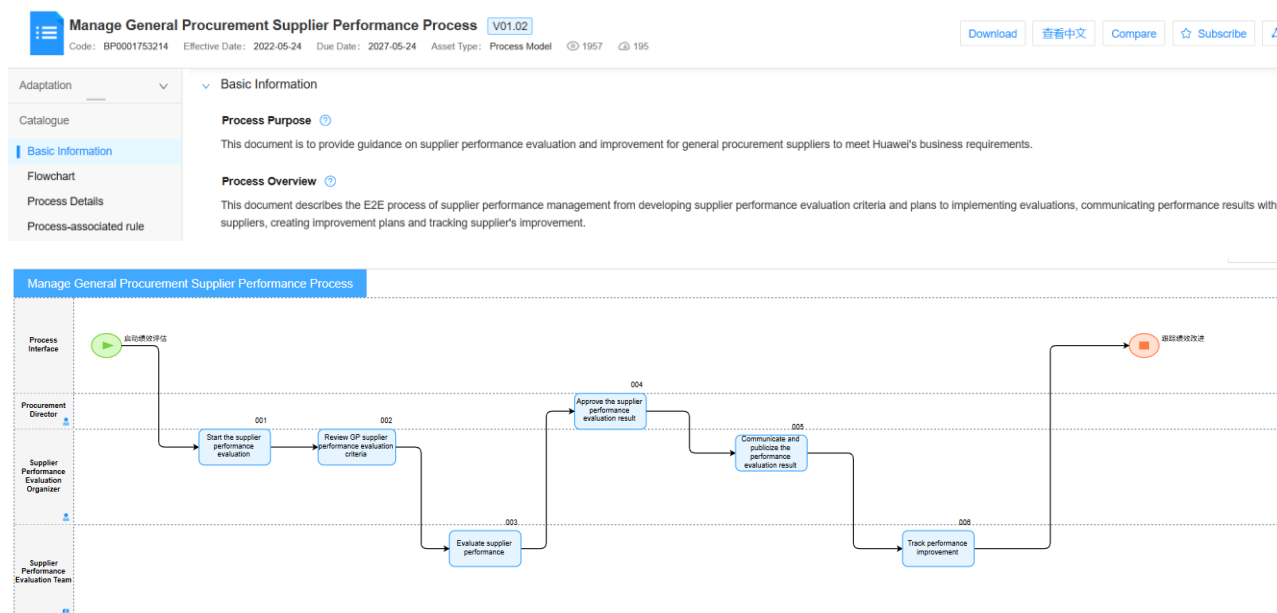


Figure 3-11 General Procurement Supplier Performance Process

3.6 Quality manuals and training

The current version of Huawei quality management manual is effective on 26 January 2022 and due on 26 January 2027. The manual includes Company vision, mission and value; Quality objectives, policies and strategies; Management system architecture etc. DNV found the quality manuals of adequate detail to meet the requirements established in the ISO 9001 standard.

During the factory visit, DNV has been shown some quality management slides. It is highlighted that a closed loop has been introduced to the quality control system. Once any defect or issue has been found, the problem will be assigned to relevant departments - design, materials, production if necessary. And all the operations will be online which will be easily traced.

Huawei maintains a structured training plan for new workers, comprising three levels: company-level, department-level, and factory-level training. The duration of training varies depending on the position; however, the average training period for new workers is approximately three months. During this period, new workers are required to wear designated armbands for identification. Upon completion of the training period, an on-boarding qualification assessment record is completed, with an example provided in **Figure 3-12**. The assessment includes written examinations covering health and safety and theoretical knowledge, as well as a practical operation evaluation. During the practical assessment, workers are also asked targeted questions to confirm their understanding of key operational requirements. DNV views this formal employee qualification and authorization process positively, as it demonstrates structured workforce competency management, documented verification of employee qualifications, and traceability of training and authorization records.

DNV also inspected the regular training. Huawei conducts annual training plans for regular training. The training plan for 2025 refers to **Figure 3-13**. The 2025 annual training plan demonstrates a well-structured competency maintenance program covering quality management, manufacturing process control, assembly operations, equipment operation, safety, technical skills, and safety awareness to address the needs for different departments and employees. Training is planned at defined intervals throughout the year, reflecting a systematic approach to maintaining workforce competency, operational consistency, and continuous improvement. The training framework indicates a mature approach to workforce qualifications and continuous improvement. DNV finds training system meets expectations.

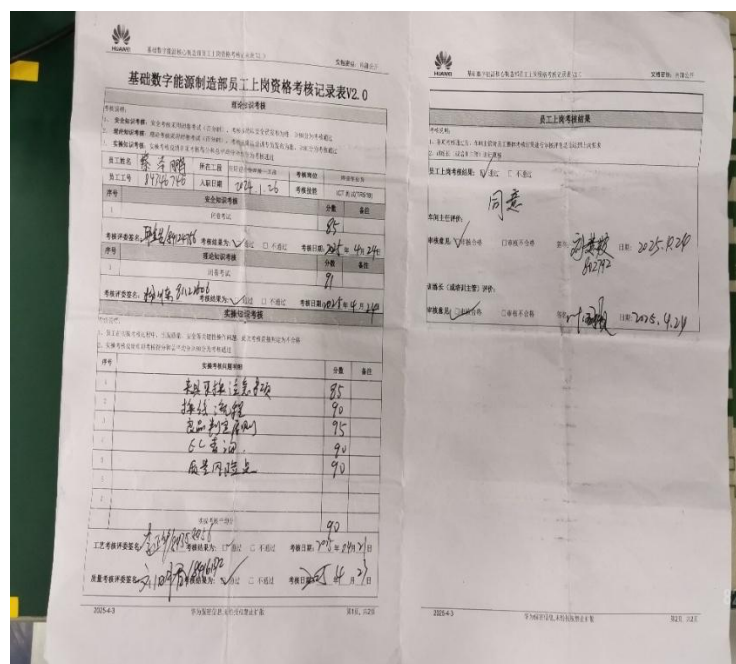


Figure 3-12 On-boarding qualification assessment record sheet

2025年数字能源核心制造部年度培训计划																			
序号	类别	课程管理	培训对象	培训形式	最低频次	培训效果验证	一季度			二季度			三季度		四季度				备注
							1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	
4	质量专项知识培训	QCC专项知识培训	质量改善相关人员	面授	1次/季度	出席	▲												
5		质量改进及常用工具方法培训	基层管理者、后备、骨干员工	面授	1次/半年度	心得				▲		▲				▲		▲	
6		华为制造质量管理体系介绍	质量管理者及改善相关人员	面授	1次/年度	闭卷考试								▲					
7		精益生产基础知识	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试							▲						
8	精益生产	时间观图表	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试													
9		工程能力组合分析和改善	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试								▲					
10		标准作业组合分析和改善	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试									▲				
11		标准作业分析和改善	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试										▲			
		生产作业M3手元化	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试											▲		
		精益生产线设计 (LLD)	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试												▲	
12	精益管理者训练营	快速换线	精益生产改善人员、基层管理者	面授	1次/年度	闭卷考试											▲		
13		TW角色认知	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
14		生产现场安全管理机制-工作级	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
15		生产现场事务内控管理——工作级	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
16		生产现场质量管理实践——工作级	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
17		生产交付管理——工作级	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
18		成本管理改善——工作级	基层管理者、后备	面授	1次/半年度	闭卷考试					▲								▲
19		企业文化熏陶	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
20		T-1生产系统	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
21		作业类员工培训与处理	基层管理者、后备	面授	1次/半年度	闭卷考试							▲		▲				▲
22	工业工程专项能力提升	生产现场核心价值观传承	基层管理者、后备	面授	1次/半年度	闭卷考试						▲		▲					▲
23		现场作业手法和节拍改善	基层管理者	面授	1次/年度	闭卷考试										▲			
24		车间科学管理循环SMC	基层管理者	面授	1次/年度	闭卷考试										▲			
25		按标准作业及改善、进阶	基层管理者	面授	1次/年度	闭卷考试											▲		
26		有效沟通及主持会议	基层管理者	面授	1次/年度	闭卷考试												▲	
27		安全管理	安全管理工具及应用	基层管理者、后备、骨干员工	面授	1次/年度	出席			▲									
28	通用机械安全培训		基层管理者、后备、骨干员工	面授	1次/半年度	闭卷考试					▲								
29	施工安全管理培训		基层管理者、后备、骨干员工	面授	1次/半年度	出席							▲						
30	生产现场安全管理培训		基层管理者、后备、安全员	面授	1次/年度	出席									▲				
31	现场5S培训		经理、基层管理者	面授	1次/年度	心得							▲						
32	HR必备知识		绩效管理基础知识	管理者	面授	1次/年度	出席	▲										▲	
33		目标制定管理	管理者	面授	1次/年度	出席	▲											▲	
34		工作教导 (理论培训)	一线员工	面授	1次/半年度	闭卷考试				▲									
35		工作教导 (实操培训)	一线员工	面授	1次/半年度	闭卷考试					▲								
36	入职引导培训	华为文化 (制造部)	新员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
37		人力资源部规章制度 (制造部)	新员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
38		制造部品质意识培训	新员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
39		网络与信息安全 (制造部)	新员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
40		安全管理 (制造部)	新员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
41		防静电基础知识 (制造部)	新员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
42		生产现场管理要求 (制造部)	新员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
43		质量意识提升	新员工	面授	例行	答辩	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
44	公共课培训	新员工安全教育培训	新员工	面授	例行	答辩或考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
45		内控及信息安全知识 (能源)	新员工	面授	例行	答辩	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况
46	操作指导	岗位操作指导书 (能源)	一线员工	面授	例行	闭卷考试	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	根据新员工入职情况

Figure 3-13 Training plan for 2025

3.7 Incoming quality inspection and test

Component quality is critical for the good reliability of inverter assemblies. Huawei implements an industry standard incoming inspection process for the materials used for the inverter products, as shown in **Figure 3-14**.

Huawei verifies that the material received from their suppliers. When a defective material is detected by an inspector, a MITR stream in the MES+ system should be submitted to MQE engineer, process engineer and factory affairs engineer. After double checking defects by these engineers, return of the materials process will be triggered. And then the stream will be forwarded to supply chain product planner. The planner will check if the material is urgent and if MRB requires and then enter the final inspection conclusion.

Huawei also provided a document describing the incoming materials inspection, including material receiving and inspection, confirming inspection environment and standards as well as testing and result reporting. Generally, DNV finds it reasonable.

DNV inspected the On-line incoming quality inspection process and an example of the defect conclusion as shown in **Figure 3-15**.

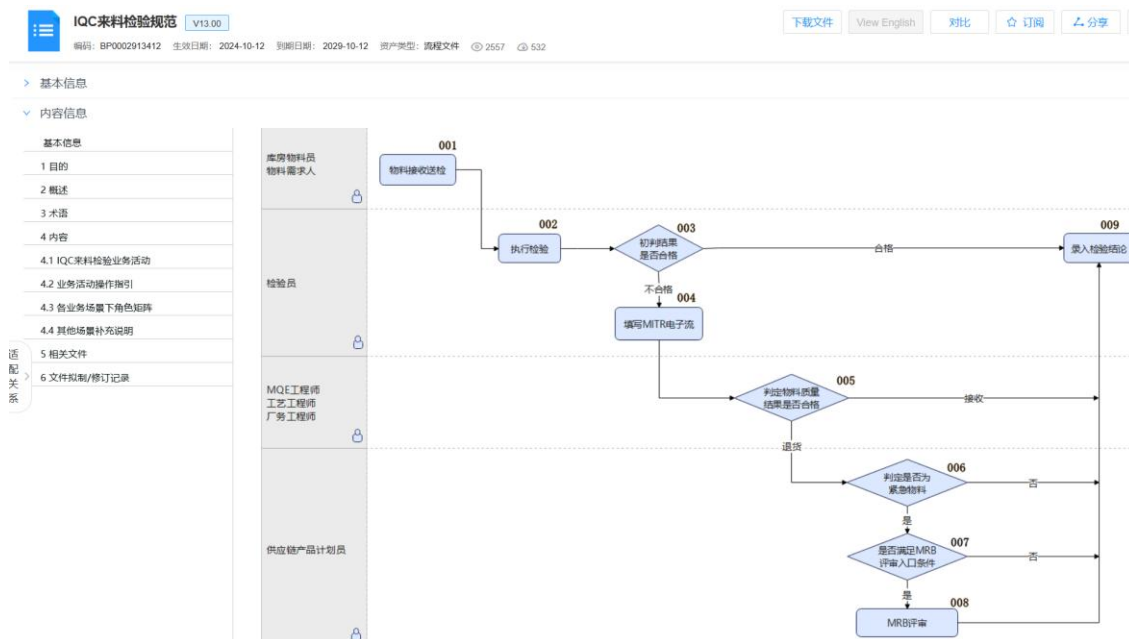


Figure 3-14 On-line incoming-material quality inspection process

查看结论

编码: 21012759-002 ; 收据号: / ; 检验单号: IQCF25111807001

批量结论: 不合格	责任归属: 供应商	是否召回: ☐ 是 ☒ 否
抽样数: 20	严重缺陷数: 1	轻微缺陷数: 0
领料数量:	接收数量: 0	退货数量: 280
Mitr单号: MITRI251118001C	检验员:	供应商QC:
替代单号:	处理方式:	备注信息: 不良
工装仪器: 目视		

▼ 缺陷信息

是否属实	缺陷大类	缺陷类型描述	缺陷大类细化描述	缺陷代码
1 属实	功能性能缺陷			

Figure 3-15 An example of incoming material inspection conclusion with defect

The mechanical housing of the product corresponds to the metal cabinet structure of the inverter, which is a key part of incoming material. IQC will be moved forward to the corresponding supplier part. Huawei keeps six (6) – eight (8) employees staying at the supplier's factory to make sure the quality of the incoming materials. Commonly, the employees will take shift for one (1) year. Huawei summarised four principles for the IQC moving forward, which are standard forward, equipment forward, organization and management method forward as well we IQC capability forward. DNV view this a positive approach for incoming material quality.

3.8 Inverter PCB assembly

PCB assemblies are fully executed and tested by Huawei itself. The assembly and tests of the inverter PCB are automatically with just a few workers to operate in case any issues are found. The test results are uploaded to the MES+ system. Engineers can easily get the authorised data from the MES+ system to identify any issues.

PCB assemblies require strict ESD (Electro-Static discharge) protection, which will harm to the electronic components and devices. Before entering the floor, ESD detection is required as shown in **Figure 3-17**.



Figure 3-16 PCB assembly



Figure 3-17 ESD detection

Huawei set up a Worker Grape Chart Noticeboard to display the mood of workers. The noticeboard reflects the mood of each worker. There are three options happiness, unhappiness or just common. Meanwhile, worker leaders will also reflect the performance of each worker onto the noticeboard. DNV views it has positive effect on the quality of the product.



Figure 3-18 Worker grape chart noticeboard

3.9 Inverter assembly

The assembly process for inverter components is organized by workstation. Component kits are pre-assembled and assigned by work order, with tasks initiated and completed at the designated workstation. Custom fixtures and automated tools are used to support accurate assembly and maintain tight tolerances for power stack components. The Manufacturing Execution System (MES+) is used to trace inverter components throughout the process. In addition, electronic Standard Operating Procedures (SOPs) available at each workstation guide operators through the required steps in the correct sequence, as shown in **Figure 3-20**. A process route for inverter test is illustrated in **Figure 3-19**.

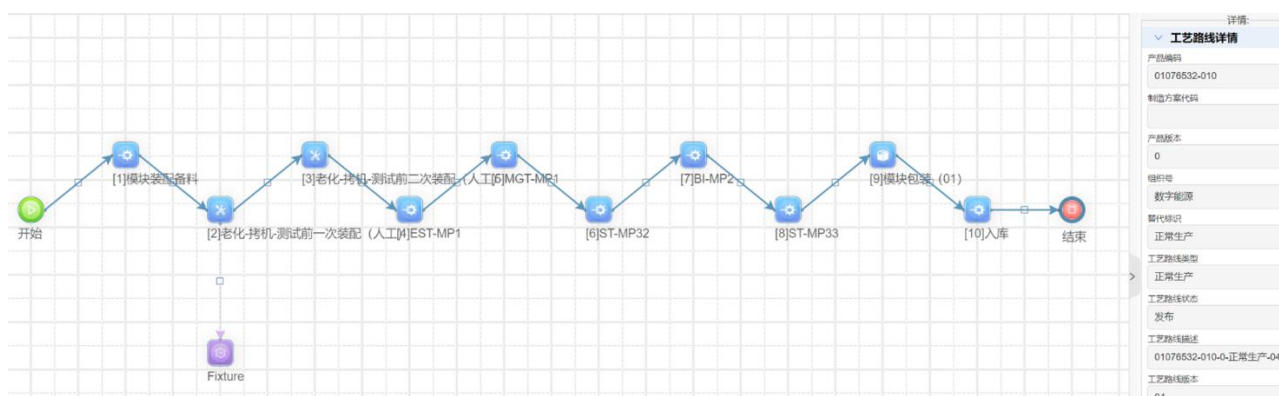


Figure 3-19 Electronic SOP

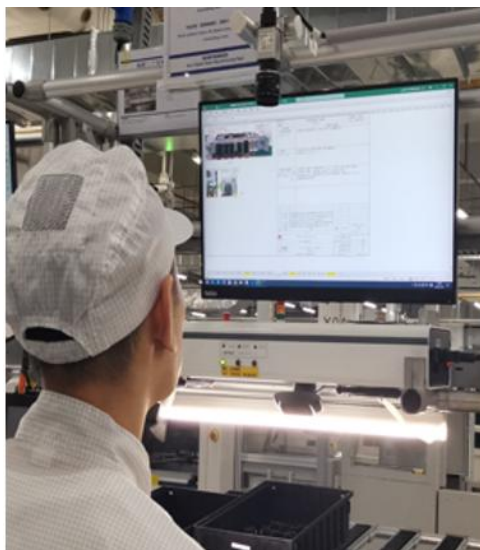


Figure 3-20 Electronic SOP

3.10 Final inspection

Each inverter undergoes a final inspection which checks for visual damage to the enclosure and any other visual sign that shows that any part of the inverter is not in line with the technical or visual requirements of the equipment. If the inverter is acceptable, it is a green-coloured pass stamp and prepared for shipment as **Figure 3-21**.



Figure 3-21 Inverter with a PASS stamp

3.11 Packing and shipping

The packing station has a sorting list for packaging, as shown in **Figure 3-22**, which demonstrates what tools and materials are required in the station. When a worker arrives at the station, he should check the list first and then start to work. DNV also found some other stations have similar sorting list and views it is a positive approach.

The inverter is mounted on a wooden skid, as shown in **Figure 3-22**, which is taken during the factory visit. Each pallet has two inverters inside. Several warning stickers with different messages are attached to package highlighting the appropriate direction to place the inverter and highlighting lithium battery is inside the equipment.

According to the packing information provided by Huawei, there will be three kinds of containers including 20-foot GP containers with 10 pallets / 20 inverters, 40-foot GP container with 21 pallets / 42 inverters and 40-foot HQ container with 42 pallets / 84 inverters. The above typical containers are commonly used in shipping. Furthermore, based on communication with Huawei during factory visit, container layouts can be also simulated by software to know how to better use the container room.



Figure 3-22 Packing

4 TECHNICAL EVALUATION

The technical evaluation describes the features, ratings, limitations, and physical attributes of the SUN2000-330KTL-H2 inverter.

4.1 Product Overview

The Huawei SUN2000-330KTL-H2 is a utility-scale, three-phase, transformer less string inverter designed for high-capacity photovoltaic plants. It operates at a maximum input voltage of 1,500 V DC and incorporates six independent MPPT trackers, each supporting up to 65 A. With a nominal AC active power of 275 kW (up to 330 kW @30°C) and a rated output AC voltage of 800 V, the inverter achieves a peak efficiency of $\geq 99.0\%$ and a European efficiency of $\geq 98.8\%$, ensuring minimal conversion losses across a wide load range.

The inverter integrates advanced protection and diagnostic features, including Smart String-Level Disconnection (SSLD) for rapid fault isolation, type II surge arresters on both AC and DC sides, anti-islanding, DC reverse-polarity protection, residual current monitoring, and string-level current detection for precise fault identification. An IP66-rated enclosure, smart air-cooling system, and operating temperature range of $-30\text{ }^{\circ}\text{C}$ to $+60\text{ }^{\circ}\text{C}$ enable reliable outdoor deployment even in harsh climates, with no derating required up to 4,000 m altitude.

For communication and monitoring, the SUN2000-330KTL-H2 offers LED indicators, WLAN access via a mobile app, USB, MBUS, and RS485 interfaces, supporting both local commissioning and integration into plant-level SCADA or PPC systems. IV-curve diagnosis capabilities and waterproof AC connectors further simplify maintenance and ensure long-term operational integrity. Measuring $1,048 \times 732 \times 395\text{ mm}$ and weighing 112 kg, the inverter features relatively compact design that facilitates efficient handling and installation in large-scale commercial and utility solar plants.

The inverter is certified to international safety and performance standards, including IEC 62109-1/2 for power converter safety, IEC 62116 for anti-islanding protection, and IEC 61727 for PV system utility interface requirements. Compliance with electromagnetic compatibility standards IEC 61000-6-1/2/4 ensures robust operation in a wide range of electrical environments, while adherence to these globally recognized benchmarks facilitates deployment in multiple regulatory markets.

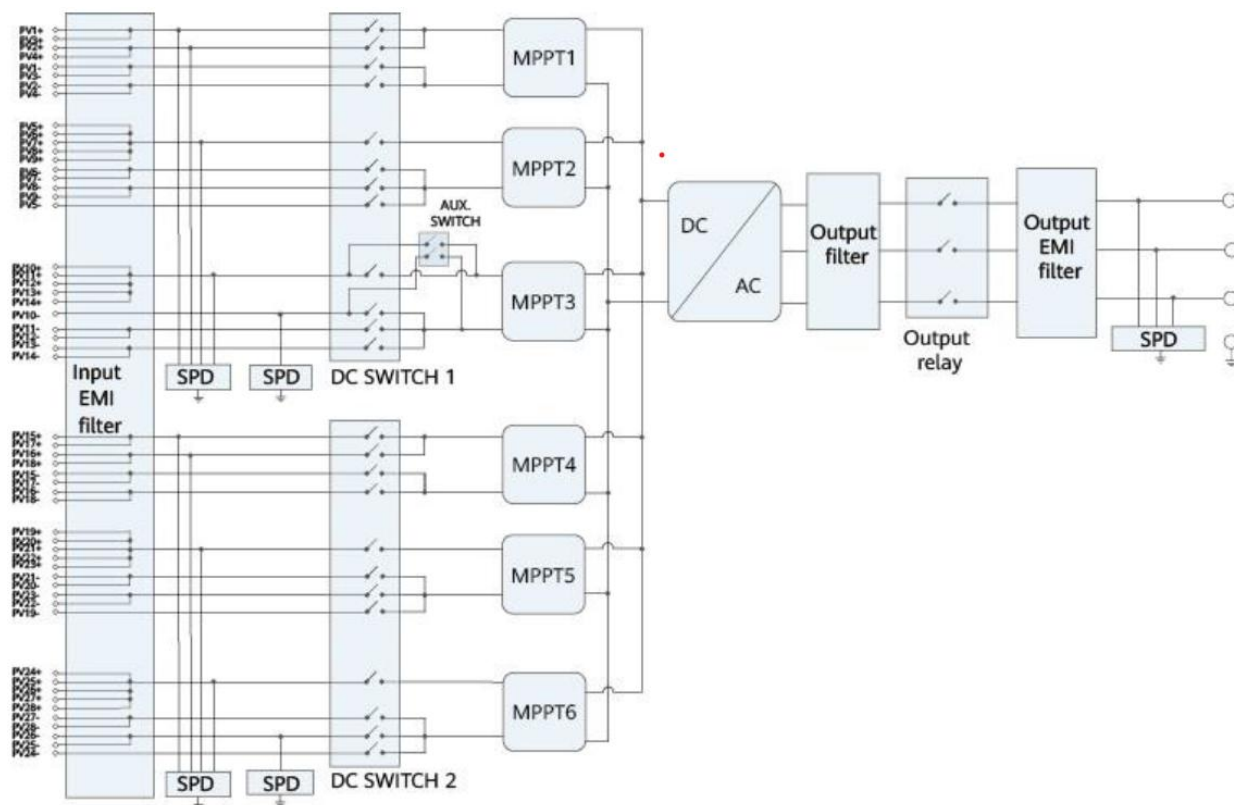
A typical SUN2000-330KTL-H2 is shown in Figure 4-1 below:



Figure 4-1 SUN2000-330KTL-H2 Smart String Inverter [18]

4.2 Product Architecture / Topology

Solar photovoltaic (PV) inverters convert the dc electricity generated by PV modules into ac electricity for interfacing with an electric utility grid. The way in which this is performed depends on many factors including the required ac and dc voltage levels, current and power levels, temperatures, grounding configurations, advanced control or protective features, cooling methods, cost, and advancements of semiconductor technology, among many others. In addition to the semiconductor type and configuration, other important topology considerations include the type and arrangement of components required to satisfy the various protective, safety, and functional requirements of the inverter.



IS18W00009

Figure 4-2 Huawei SUN2000-330KTL-H2 Inverter Topology [19]

As shown in the Figure 4-2, SUN2000-330KTL-H2 employs a three-phase, two-level Voltage Source Inverter (VSI) bridge topology utilizing Insulated Gate Bipolar Transistors (IGBTs) as the main switching devices. This topology is a mature and widely adopted architecture in the PV industry, valued for its simplicity, efficiency, and proven reliability.

The inverter processes DC power from up to 28 PV strings through six independent MPPT circuits. Each MPPT stage incorporates a DC/DC converter to optimize the operating point of the connected PV strings, ensuring maximum energy yield under varying irradiance and temperature conditions, including partial shading or module mismatch. The conditioned DC power is then fed into the IGBT-based DC/AC conversion stage, where high-frequency switching generates a three-phase AC output. This AC output is subsequently filtered by an LCL-type output filter to produce a clean, grid-compliant sinusoidal waveform.

Surge Protection Devices (SPDs) are installed on both the DC input and AC output sides to protect the inverter against transient overvoltage. Input and output EMI filters further suppress conducted and radiated electromagnetic noise, ensuring compliance with international grid and EMC standards. For operational safety, DC switches are provided for isolation on the input side, enabling safe maintenance and fault segregation. On the AC side, an output relay—

comprising two series-connected relays for redundancy—facilitates secure disconnection of the inverter from the grid in case of fault, shutdown, or protection events.

4.3 Technical Specifications

Datasheets for SUN2000-330KTL-H2 is given below in . Note that the inverter model number approximates the ac power rating of the inverter at an ambient temperature of 30°C. The data sheets show inverter dc current limits and ac power ratings (nominal) at 50°C to provide system designers with adequate thermal data to match PV arrays with inverters, and to estimate system performance.

The inverters are rated in kVA / VA, not W / kW, meaning that the system designer/operator can apply the kVA rating to produce real power, reactive power, or a combination of both. All the details of technical specifications are highlighted in the datasheet below.

► SUN2000-330KTL-H2

Smart String Inverter

For MEA, Eurasian



Max. Efficiency
≥ 99.0%



Smart Connector-level Detection (SCLD)



Smart Self-cleaning Fan (SSCF)



IP66 Protection



MBUS Supported



Smart String-level Disconnection (SSLD)

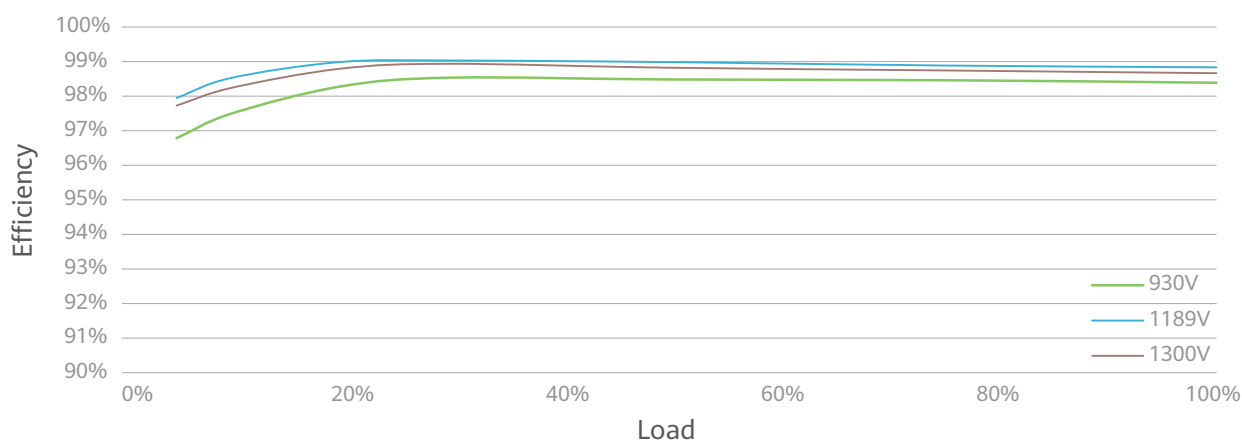


Smart IV Curve Diagnosis Supported

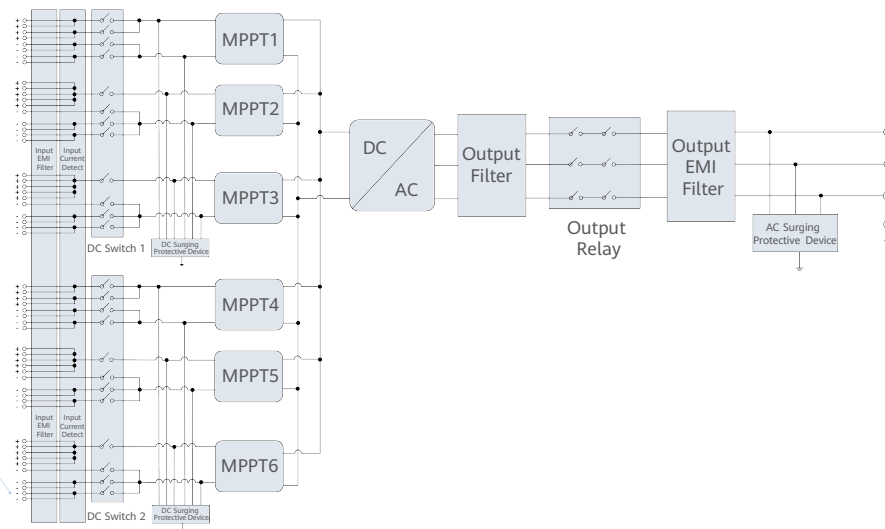


Surge Arresters for DC & AC

Efficiency Curve



Circuit Diagram



Technical Specifications

Efficiency	
Max. Efficiency	> 99.0%
European Efficiency	> 98.8%
Input	
Max. Input Voltage	1,500 V
Number of MPPT	6
Max. Current per MPPT	65 A
Max. Short Circuit Current per MPPT	115 A
Max. PV Inputs per MPPT	4/5/5/4/5/5
Start Voltage	550 V
MPPT Operating Voltage Range	500 V ~ 1,500 V
Nominal Input Voltage	1,080 V
Output	
Nominal AC Active Power	275,000 W ¹
Max. AC Apparent Power	330,000 VA
Max. AC Active Power (cosφ=1)	330,000 W
Nominal Output Voltage	800 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Nominal Output Current	198.5 A
Max. Output Current	240.3 A
Adjustable Power Factor Range	0.8 LG ... 0.8 LD
Total Harmonic Distortion	THDi < 1% (Rated)
Protection	
Smart String-level Disconnection (SSLD)	Yes
Smart Connector-level Detection (SCLD)	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Detection	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
Residual Current Detection Unit	Yes
Communication	
Display	LED Indicators, WLAN + APP
USB	Yes
MBUS	Yes
RS485	Yes
General	
Dimensions (W x H x D)	1,048 x 753 x 395 mm
Weight (with mounting plate)	≤ 112 kg
Operating Temperature Range	-25°C ~ 60°C
Cooling Method	Smart Air Cooling
Max. Operating Altitude without Derating	4,000 m
Relative Humidity	0 ~ 100% (Non-condensing)
DC Connector	HH4SMM4TMSPA / HH4SFM4TMSPA
AC Connector	Support OT / DT Terminal (Max. 400 mm ²)
Protection Degree	IP 66
Anti-corrosion Protection	C5-Medium
Topology	Transformerless
Standards Compliance	
IEC 62109-1/-2, IEC 62920, IEC 60947-2, EN 50549-2, IEC 61683, etc.	

1: Environmental temperature is 50°C

4.3.1 Environmental Characteristics

Figure 4-3 provides more information about the environmental limitations for the Huawei inverters:

General	
Dimensions (W x H x D)	1,048 x 732 x 395 mm
Weight (with mounting plate)	≤112 kg
Operating Temperature Range	-30 °C ~ 60 °C
Cooling Method	Smart Air Cooling
Max. Operating Altitude without Derating	4,000 m (13,123 ft.)
Relative Humidity	0 ~ 100%
AC Connector	Waterproof Connector + OT/DT Terminal
Protection Degree	IP66
Topology	Transformerless

Figure 4-3 SUN2000-330KTL-H2 environmental conditions [18]

The IP66 rating, as defined by IEC 60529 standard, indicates how well an enclosure protects against dust and water. A rating of "6" for solids means the enclosure is fully sealed against dust, even in extreme conditions. The second "6" means it can withstand pressurized water streams. This makes IP66 enclosures, such as the one certified in the Huawei SUN2000-330KTL-H2 inverter [21], ideal for tough outdoor environments, like dusty farms, coastal areas, or industrial zones. Essentially, IP66 gives reliable protection in site conditions.

In addition, the operating temperature range is -30° to 60° C, and 0-100% relative humidity. The derating curve of output power vs temperature is shown in Figure 4-4. The thermal performance of the SUN2000-330KTL-H2 inverter demonstrates operational stability across the enunciated ambient temperature range. From -30°C up to 30°C, the inverter maintains its full rated output of approximately 330 kW without any power limitation. Beyond 30°C, the inverter initiates a gradual derating process to prevent thermal stress on internal components. This reduction becomes more pronounced as temperatures rise, with output power decreasing steadily through 50°C to level of 275 kW and then falling significantly by 60°C to level of 150 kW. Such behavior is a standard protective feature in high-capacity inverters, ensuring long-term reliability and safety under elevated temperature conditions commonly encountered in desert or industrial environments. DNV recommends proper system design for this thermal derating when deploying the inverter in hot climates.

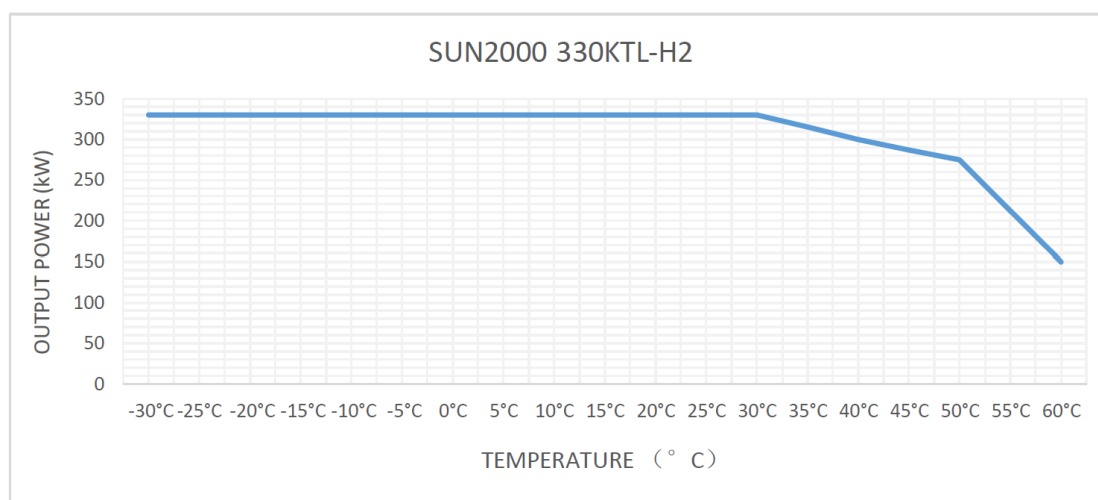


Figure 4-4 SUN2000-330KTL-H2 output power derating curve for temperature [22].

The SUN2000-330KTL-H2 inverter features a robust heat dissipation design that ensures reliable operability under high-temperature conditions, making it well-suited for demanding environmental conditions. The inverter employs a forced

air-cooling system with stacked parallel heat dissipation structure, combining radiators and heat exchangers to enhance cooling efficiency and prolong component lifespan. The design separates the internal architecture into a front high-protection cavity and a rear heat dissipation cavity with direct ventilation, where ambient air is drawn in from the bottom, passes through radiators and inductors, and is expelled from the top, effectively managing internal temperatures. Under full load and an ambient temperature of 40°C with solar radiation of 1120 W/m², thermal simulations show the maximum temperature of the inverter module's heat dissipation substrate under the inverter module reaches 90.5°C and heat dissipation substrate under the boost module reaches 80.3°C temperature, which remains safely below the allowable limit as per IEC 60085. This demonstrates the inverter's capability to operate efficiently and reliably in high-temperature environments, supporting its durability from an environmental resilience standpoint.

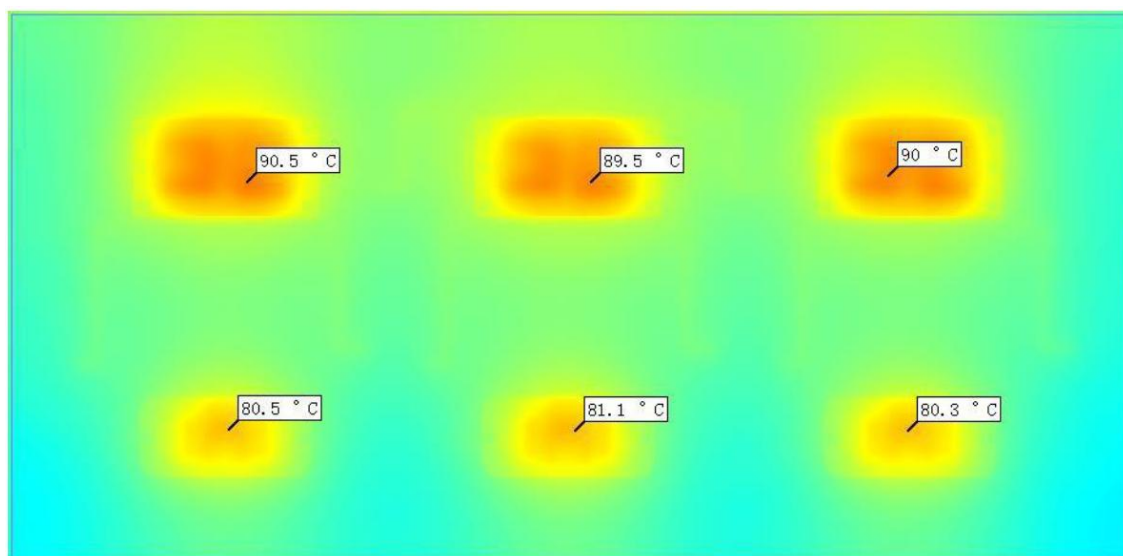


Figure 4-5 Temperature cloud diagram of thermal simulation [24]

At elevated altitudes, air density decreases, resulting in reduced convective cooling capacity and diminished heat dissipation performance for power electronic equipment such as inverters. This reduction in cooling efficiency may elevate internal component temperatures, potentially impacting long-term reliability and operational stability.

Furthermore, lower air density increases the mean free path of electrons, which in turn raises the risk of electrical breakdown and partial discharge phenomena, particularly at high DC voltages. To mitigate these risks and maintain compliance with insulation coordination and safety standards, the maximum permissible DC input voltage of the inverter is derated at higher altitudes.

In high-altitude installations, careful string sizing and voltage planning are therefore essential to ensure that the DC input voltage remains within the safe operational limits defined by the inverter's altitude derating curve. Improper configuration may result in excessive input voltage, triggering protective shutdowns or risking inverter damage.

The elevation rating is 4,500 m according to datasheet [18], which is adequate for most locations in MEA. Huawei provided the chart in Figure 4-6 for derating for altitude above 4000 meters [22]. The graph shows a DC voltage drop (derating) of approximately 20 volts for every 100 meters increase in elevation post 4000m.

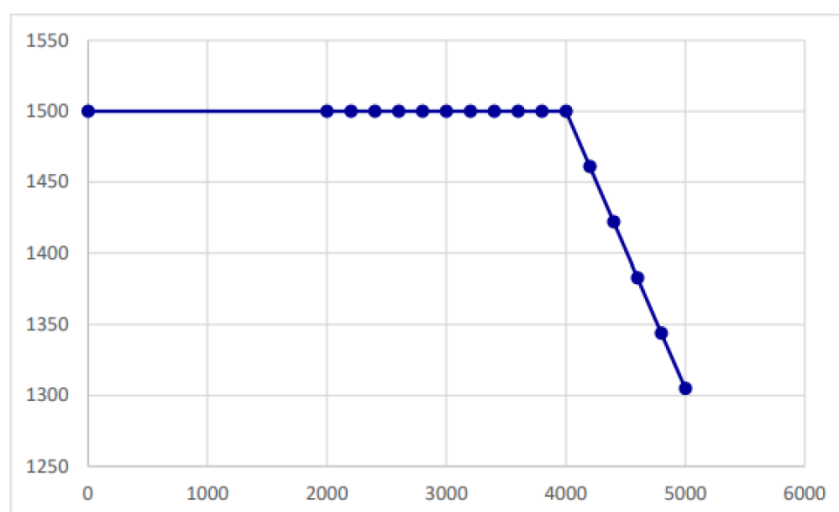


Figure 4-6 SUN2000-330KTL-H2 DC power derating curve for altitude [22].

4.3.2 Inverter Installation & Ventilation Conditions

According to the user manual [19], the inverter should be installed outdoors or in well-ventilated indoor environments to ensure safe and efficient operation. Installation sites exposed to direct sunlight should be avoided; in warmer climates, shaded or north-facing walls are recommended to reduce thermal load. The inverter must not be installed in saline, corrosive, or explosive environments unless the device is specifically rated for such conditions. Proximity to heat sources or locations with restricted airflow should also be avoided. To maintain adequate ventilation and allow for safe maintenance, the manual specifies a minimum clearance of 300 mm on each side of the inverter.

4.3.3 Power Quality & Grid Support

This section provides a review of inverter characteristics that affect the supplied power quality as well as inverter features that provide support to the AC grid. DNV notes that the inverter currently under review is a grid-following inverter..

DNV reviewed the IEC 61727 compliance test report and certificate [28], which demonstrate conformity with grid interconnection requirements related to harmonics, DC injection, flicker, voltage and frequency operating limits, synchronization, and power factor. In addition, DNV reviewed the IEC 62910 compliance test report and certificate [27], covering voltage ride-through capability, reactive power response, and recovery performance during voltage disturbances. Compliance with anti-islanding requirements was verified through the IEC 62116 test report [29], which confirms the inverter's ability to detect and cease energizing a de-energized grid.

Based on the available test reports and supporting documentation, the following section summarizes the power quality performance and grid support functions of the Huawei SUN2000-330KTL-H2 inverter.

4.3.3.1 Harmonic Distortions

The test report [28] confirms that the Huawei SUN2000-330KTL-H2 inverter exhibits low harmonic distortion, meeting the requirements of the most of the country's transmission code (<5%). For the SUN2000-330KTL-H2, total harmonic current distortion (THDi) was measured at 0.67%, 0.54%, and 0.56% across the three phases (L1, L2, L3), all well below the standard limit of 5%. These results validate the inverter's effective harmonic suppression through advanced modulation and filtering, ensuring compliance with power quality standards and reliable integration into sensitive grid environments.

4.3.3.2 Power Factor

Huawei Sun 2000 series inverters can operate with 0.8 lagging or 0.8 leading power factor range. The Sun 2000 inverters also have the capability to contribute reactive power at night, when PV solar power is not available, acting as a reactive power compensator under potentially external command.

In Figure 4-7, the relationship between available real and reactive power is presented in the form of a PQ curve. The graph readily conveys the concept that for an inverter limited in kVA, at or near rated power, real power may be sacrificed to provide reactive power.

The test report confirms that the Huawei SUN2000-330KTL-H2 inverter meets its specified reactive power capabilities, including operation at power factors below 0.8. As mentioned in the report [25], the inverter delivers up to -90,388 Var of inductive reactive power at 0% active power output and maintains -89,200 Var even at 100% rated power (275.47 kW), corresponding to a lagging power factor of 0.951. While the tested grid code (Abu Dhabi Electricity Distribution Code, Version 3.0) requires operation down to $\cos \phi = 0.95$, the inverter's design allows for deeper reactive power support. Although steady-state operation below 0.8 power factor is not explicitly tested in this report, the inverter's thermal and electrical design, combined with its ability to deliver high reactive current during transients, suggests it can support such operation if configured and permitted by grid codes. Therefore, the datasheet claims are validated for standard grid requirements, with evidence indicating potential for extended reactive power capability under specific conditions.

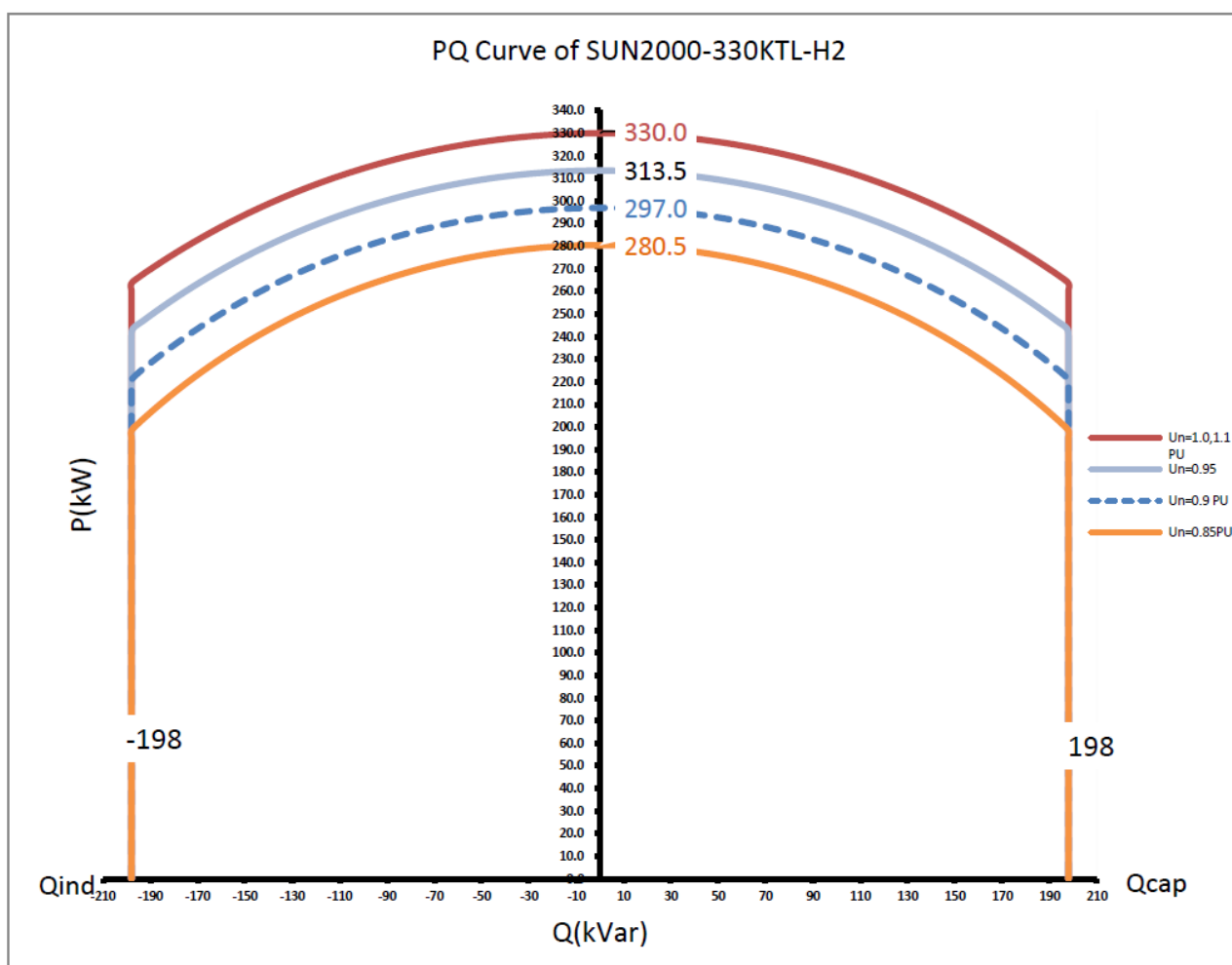


Figure 4-7 SUN2000-330KTL-H2 Inverter PQ Curve Diagram [22]

4.3.3.3 DC Current Injection

According to IEC 61727:2004 Clause 4.4, the inverter must not inject DC current exceeding 1% of its rated output current. The test report shared by Huawei [28] evaluates the DC current injection performance of the Huawei SUN2000-330KTL-H2 inverter in accordance with the IEC 61727:2004, confirming compliance with grid interconnection requirements. Test results show DC injection values of 0.17–0.55 A across all phases and load levels, corresponding to less than 0.3 % of rated current—well within the IEC limit.

This low DC current injection is achieved through the inverter's transformer less design with advanced control algorithms and galvanic isolation monitoring, which effectively prevent any net DC offset in the output current. The test results demonstrate that the SUN2000-330KTL-H2 meets the required standards, ensuring safe and compatible operation in utility-scale solar plants.

4.3.3.4 Voltage Ride-Through (LVRT / HVRT)

The dynamic voltage ride-through (LVRT/HVRT) capability of the SUN2000-300KTL-H2 inverters has been validated in accordance with IEC TS 62910, demonstrating compliance with international standards for grid resilience. As per the test report [27], the inverter successfully remained connected during specified low-voltage ride-through (LVRT) events, including voltage dips down to 20% of nominal for 150 ms and 50% for 1 second, without tripping or losing synchronization. During these events, the inverter injected reactive current (up to 1.21 p.u.) to support grid voltage recovery, in line with dynamic reactive current injection requirements. For high-voltage ride-through (HVRT), the inverter stayed online when voltage rose to 110% of nominal for 1 second, maintaining stable operation and resuming normal power output after voltage normalization. The response time for reactive current injection was measured at 0.32 seconds, well within the required thresholds. These results confirm that the inverter meets the dynamic voltage ride-through performance criteria defined in IEC TS 62910, ensuring reliable grid support during transient disturbances and enhancing its suitability for grid-critical applications.

4.3.3.5 Frequency Ride-Through (FRT)

The Huawei SUN2000 series inverter demonstrates reliable Frequency Ride-Through (FRT) capability under grid frequency deviations, as validated by testing in accordance with IEC 61727:2004 Clause 5.2.2 [28]. During the 50 Hz test, the inverter operated continuously within the ± 1 Hz permissible range and demonstrated reliable protection response when the frequency went outside this window.

The under-frequency trip occurred at 48.99 Hz with a measured disconnection time of 0.275 s, while the over-frequency trip occurred at 51.01 Hz with a measured disconnection time of 0.277 s. These disconnection times include the intentional protection delay applied during testing and are consistent with the allowance in IEC 61727 for short time delays intended to avoid nuisance tripping during transient frequency disturbances.

Following restoration of grid frequency within acceptable limits, the inverter reconnected automatically after approximately 62.8 s, in compliance with Clause 5.4 (response to utility recovery). Overall, the test results confirm compliance with IEC 61727 frequency protection requirements.

This confirms the inverter's ability to tolerate grid frequency fluctuations—common in weak or islanded grids—without disconnecting, thereby supporting grid stability and minimizing unnecessary generation loss. The robust FRT performance enhances the system's suitability for deployment in diverse grid environments.

4.3.3.6 Anti Islanding

The Huawei SUN2000-330KTL-H2 inverter was evaluated for unintentional islanding prevention in accordance with IEC 62116:2014, which defines the procedure for verifying an inverter's ability to detect and cease energizing a de-energized grid. As referenced in the test report [29], the inverter was subjected to loss-of-mains tests under both load and no-load conditions to simulate a utility disconnection. During testing, the inverter continuously monitored grid voltage and frequency. Upon simulated grid loss, it detected the abnormal condition and ceased to energize the utility line within 2

seconds, which is the maximum trip time permitted by IEC 62116. The tests confirmed reliable operation of the inverter's active anti-islanding algorithm, ensuring that it does not maintain power export to an isolated section of the network.

4.3.3.7 Compliance with Grid Codes

DNV was provided with a list from Huawei detailing the grid codes [30] complied with by the Huawei SUN2000-330KTL-H2 inverter. DNV has also reviewed the corresponding grid compliance certificates and test reports for several of these grid codes. The summary of reviewed and declared compliances is presented in the table Table 4-1 below

Table 4-1 Grid Codes Complied by Huawei SUN2000-330KTL-H2

Sr No	Grid Code	Description
1	IEC61727-MV800* [43]	IEC 61727 medium-voltage power grid
2	IEC 61727-MV800-60HZ* [43]	IEC 61727 (60 Hz) medium-voltage power grid
3	ABUDHABI-MV800* [33]	Abu Dhabi medium-voltage power grid
4	DUBAI-MV800*[32]	Dubai medium-voltage power grid
5	SAUDI-MV800* [31]	Saudi Arabia power grid
6	Oman-MV800*[34]	Oman power grid
7	Oman-PDO-MV800	Oman power grid
8	Kuwait-MV800	Kuwait power grid
9	Bahrain-MV800	Bahrain power grid
10	Egypt ETEC-MV800	Egypt power grid
11	UZBEKISTAN-MV800	Uzbekistan power grid
12	KAZAKHSTA-MV800	Kazakhstan power grid
13	AZERBAIJAN-800	Azerbaijan power grid
14	IRAQ-MV800	Iraq power grid
15	LEBANON-MV800	Lebanon medium-voltage power grid
16	Jordan-Transmission-MV800	Jordan power grid
17	Jordan-Distribution-MV800	Jordan power grid
18	Jordan-Transmission-HV800	Jordan high-voltage power grid
19	NRS-097-2-1-MV800	South Africa power grid
20	SA_RPPs-MV800	South Africa power grid
21	MOROCCO-MV800	Morocco power grid
22	ALGERIA-MV800	Algeria power grid
23	Mauritius-MV800	Mauritius power grid
24	NIGERIA-MV800	Nigeria medium-voltage power grid
25	Ghana-MV800	Ghana medium-voltage power grid
26	Cameroon-MV800	Cameroon medium-voltage power grid
27	NAMIBIA_MV800	Namibia power grid
28	KENYA_ETHIOPIA-MV800	Kenya low-voltage & Ethiopia medium-voltage power grid
29	ZAMBIA-MV800	Zambia medium-voltage power grid
30	KENYA_ETHIOPIA-MV800	Kenya low-voltage & Ethiopia medium-voltage power grid
31	TUNISIA-MV800	Tunisia medium-voltage power grid
32	G99-TYPEB-HV-MV800	UK G99 Type B medium-voltage power grid
33	G99-TYPEC-HV-MV800	UK G99 Type C medium-voltage power grid
34	G99-TYPED-MV800	UK G99 Type D medium-voltage power grid
35	SENEGAL-MV800	Senegal medium-voltage power grid

Sr No	Grid Code	Description
36	INDIA-MV800	India medium-voltage power grid
37	CEA-MV800	India medium-voltage power grid
38	Pakistan-MV800	Pakistan power grid

*Either compliance test report or certificate is reviewed by DNV.

4.3.4 Protective & other Features

The inverter includes comprehensive protection functions such as reverse polarity, AC short-circuit, overload, over/under-voltage and frequency, over-temperature, DC over-voltage, LVRT/ZVRT, insulation resistance monitoring, anti-islanding, and residual current detection (RCD).

It supports MBUS communication and features automatic fault logging and detailed data monitoring, including string voltage/current, MPPT power, grid parameters, temperature, energy yield, and operating times. Remote control options include start/stop commands, power factor adjustment, and active power regulation, ensuring reliable performance, grid compliance, and efficient system management.

4.3.4.1 Protection Features

The Huawei SUN2000-330KTL-H2 inverter is equipped with comprehensive protection functions designed to ensure safe, reliable, and uninterrupted operation. These include both electrical and system-level protections such as anti-islanding, overcurrent, reverse-polarity, and grounding fault protection. Additionally, the unit incorporates Type II DC and AC surge arresters, string fault monitoring, and residual current detection, providing robust defence against electrical faults and grid disturbances while maintaining compliance with international safety standards.

Table 4-2: Huawei SUN2000-330KTL-H2 Inverter protective features

Smart String-Level Disconnectors(SSLD)	Yes
Anti-islanding Protection	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Monitoring	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
AC Grounding Fault Protection	Yes
Residual Current Monitoring Unit	Yes

4.3.4.2 Potential Induced Degradation (PID) Protection

The inverter integrates with the SmartPID2000 module to actively suppress PID effects, a common cause of power loss in PV modules operating under high-voltage stress, especially in hot and humid climates. By dynamically adjusting the voltage potential between the PV string (PV+ or PV-) and ground during nighttime, the system reverses leakage currents and recovers module performance. Huawei claims up to 5–8% recovery in affected strings [26], however, the actual impact is dependent on site-specific conditions and should be evaluated at project level. Figure 4-8 explains PID protection mechanism in Huawei SUN2000-330KTL-H2 inverters.

4.3.4.3 Smart Insulation Monitoring

Beyond standard DC insulation detection, Huawei's Smart Insulation Monitoring leverages the existing PID correction circuitry and advanced algorithms to continuously assess insulation resistance on both the PV side and low-voltage control side. It provides early warnings for ground faults or insulation degradation due to moisture ingress, cable damage, or aging. The system can also be integrated with external breakers at the transformer station to enable

coordinated tripping, enhancing overall plant safety and reducing unplanned outages. Figure 4-8 below explains PID protection mechanism through insulation monitoring.

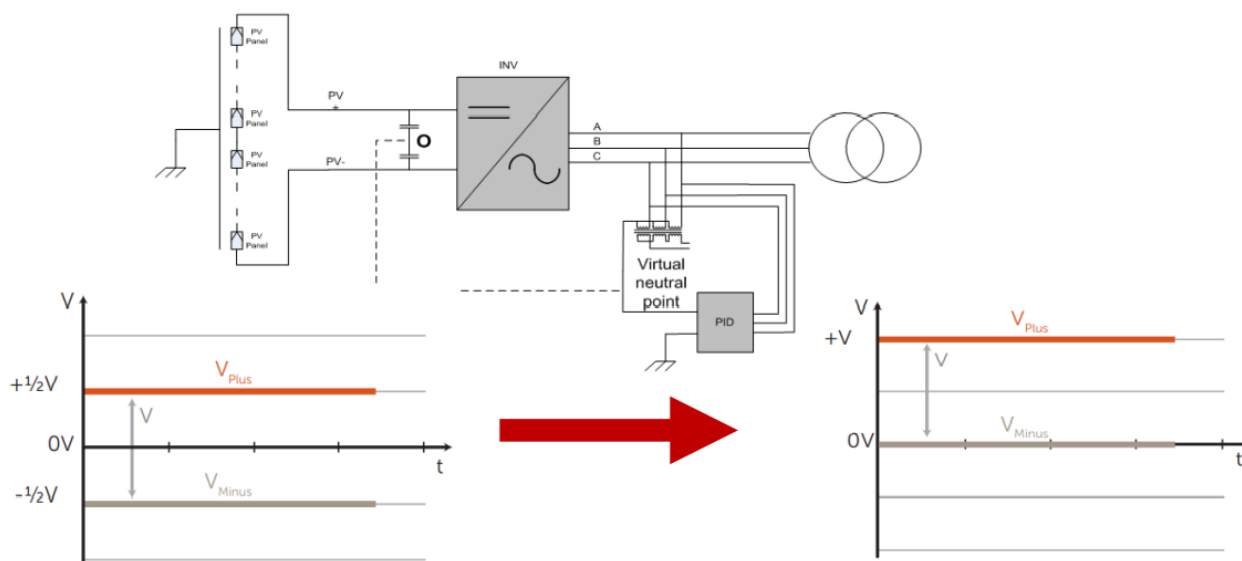


Figure 4-8: PID protection mechanism in Huawei SUN2000-330KTL-H2

4.3.4.4 Smart IV Diagnosis

This advanced diagnostic tool enables remote I-V curve tracing for each PV string without requiring on-site equipment. By analysing the shape, fill factor, and key parameters (V_{oc} , I_{sc} , P_{max}), the system identifies issues such as soiling, shading, module degradation, open circuits, or mismatch losses. Results are visualized in the FusionSolar platform, allowing operators to pinpoint underperforming strings and prioritize maintenance actions. This can reduce inspection time and improves fleet-wide availability.

While such functionality may offer operational benefits by enabling performance assessment, DNV has not independently tested or verified the capability and therefore makes no assessment regarding its effectiveness or diagnostic accuracy.

4.3.4.5 Smart Terminal Temperature Detection

This feature uses embedded temperature sensors at the DC terminal block to monitor connection points in real time. It detects abnormal temperature rises caused by poor crimping, loose terminals, or chemical corrosion—common root causes of arcing and fire hazards. When a threshold is exceeded, the system triggers alarms and can initiate automatic shutdown via the FusionSolar platform, preventing catastrophic failures. This proactive monitoring enhances safety, reduces O&M risks, and supports compliance with fire protection standards in utility-scale installations.

4.3.4.6 Smart Fan Self-Cleaning Technology

In dusty environments such as deserts or agricultural zones, air filters can quickly clog, impairing heat dissipation and leading to thermal derating. The Smart Fan Self-Cleaning system combats this by automatically reversing fan rotation during low-generation periods (e.g., early morning startup or evening shutdown), expelling accumulated dust without consuming additional energy or interrupting operation. This intelligent cleaning cycle maintains optimal airflow and cooling efficiency, ensuring consistent full-power output and extending inverter lifespan—critical for reliable performance in harsh Middle Eastern and African climates.

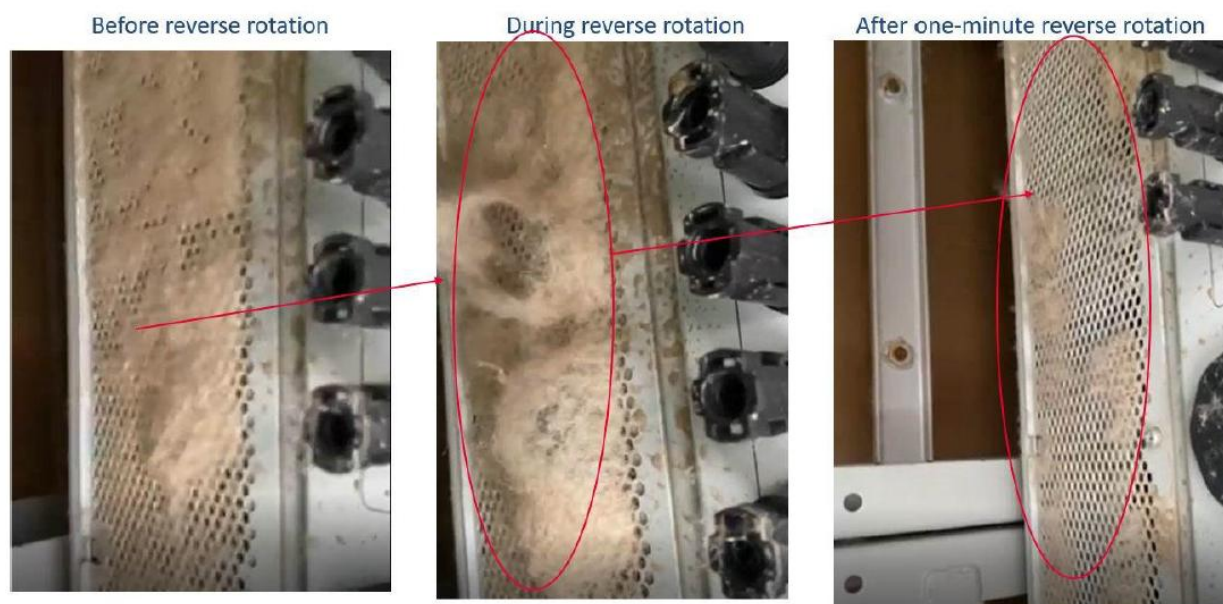


Figure 4-9: Reverse rotation of the fan to remove dust in Huawei SUN2000-330KTL-H2 [26]

4.3.5 Software Description

The Smart Energy Management Software (SEMS2000) platform is Huawei's dedicated software solution for centralized monitoring and control of photovoltaic (PV), energy storage systems (ESS), and hybrid energy systems. Designed to operate at the plant level, it enables operators to supervise, analyze, and optimize system performance through a unified interface. This description is based on material extracted from the official SEMS2000 Software Training Presentation [23] provided by Huawei.

SEMS2000 offers comprehensive real-time monitoring, from overall plant status down to individual device-level diagnostics. It supports visualization of key performance indicators such as daily and cumulative energy yield, state of charge (SOC), power curves, and grid connection metrics. Customizable single-line diagrams and multi-layer dashboards allow users to detect anomalies quickly and assess system conditions effectively.

In addition to live monitoring, SEMS2000 integrates intelligent diagnostic tools, including I-V curve tracing, inverter deviation analysis, and string-level performance assessments. For ESS applications, the software enables early fault detection at the cell and pack level. These features help reduce downtime and protect long-term asset performance.

The platform also provides a flexible environment for device configuration, network topology mapping, and communication management using industry-standard protocols such as Modbus-TCP and IEC 60870-5-104. Key operations such as black-box log retrieval, report generation, and firmware upgrades can be performed remotely, streamlining plant operation and maintenance activities.

Built on Huawei's own IT stack, including Kunpeng processors and EulerOS, SEMS2000 features high-availability architecture with built-in redundancy. Security is embedded through role-based access controls, encrypted data transmission, and compliance with international standards such as IEC 62443.

DNV finds that these attributes described previously make SEMS2000 a reliable and scalable solution for modern solar and storage applications.

5 PERFORMANCE EVALUATION

This section presents the comprehensive performance assessment of the inverter under standardized and dynamic operating conditions. The evaluation encompasses product efficiency, stress testing, and Maximum Power Point Tracking (MPPT) algorithm performance, aiming to verify the inverter's operational reliability, responsiveness, and conversion effectiveness.

5.1 Product Efficiency

One of the key performance indicators for PV inverters, such as Huawei SUN2000 Series, is their conversion efficiency across a wide range of output power levels and DC input voltages. While the peak (maximum) efficiency figure is often highlighted in datasheets and typically above 98.5%, it only represents a single operating point. In practice, system efficiency varies with both input conditions and load levels.

Huawei SUN2000 Series inverters are engineered with advanced power electronics and control algorithms that maintain high efficiency across a broad range of operating conditions. In addition to peak efficiency, Huawei provides weighted efficiency values such as the European weighted efficiency, which offers a more representative measure of real performance under variable irradiance and temperature conditions.

The SUN2000-330KTL-H2 inverter datasheet lists the operating / European efficiency to be 98.8% and the maximum efficiency 99% as shown in Figure 5-1 below.

Efficiency	
Max. Efficiency	≥99.0%
European Efficiency	≥98.8%

Figure 5-1 Huawei SUN2000-330KTL-H2 efficiency [18].

Generally, the conversion efficiency is not constant but depends on the actual power level and dc voltage. It is relevant to know the efficiency at various operational levels. For fixed-tilt systems, the PV system generates energy at lower levels in the morning and in the evening, with a maximum at solar noon. Tracking systems and systems with a high ratio of PV dc capacity to the ac inverter output rating can produce high power output for longer periods of the day.

For the calculation of the operating efficiency, the IEC 61683 [35] as well as

[37] standard was followed, which DNV views positively. The table below shows the conversion efficiency as per the IEC 61683 in Table 5-1 and as per EN 50530 in Table 5-2.

Huawei attributes high level efficiency of this inverter to a few key innovations, indicated below.

- Smart Fan Self-Cleaning Technology
- Smart String-level Disconnection
- Higher MPPT Efficiency due to MPPT algorithm
 - Advanced Three-Step Tracking Algorithm – The inverter's Pre-disturbance, Confirmation, and Tracking sequence
 - Dual-Direction Power Validation – power variations in both directions within each cycle
 - Fast Startup Optimization - open-loop routine at startup of inverter
 - Balanced Speed and Stability Control – dynamic algorithm adjusts its step size to maintain an optimal balance between fast convergence and steady-state

Table 5-1 Efficiency calculation for Huawei SUN2000-330KTL-H2 as per IEC 61683

MPP condition	Input Voltage (V)	Energy Efficiency (%)						
		5%	10%	25%	50%	75%	100%	120%
UMPP max	1300	97.52	98.19	98.69	98.89	98.81	98.70	98.77
UMPP	1189	97.90	98.59	98.95	98.89	98.91	98.88	98.78
UDC,r	1080	98.38	98.38	98.53	98.61	98.52	98.36	98.60
UMPP min	930	96.55	97.47	98.28	98.53	98.41	98.28	98.42

Table 5-2 Efficiency calculation for Huawei SUN2000-330KTL-H2 as per EN 50530

MPP voltage of the simulated I/U characteristic of the PV generator		Conversion efficiency (%)								European efficiency (%)	CEC efficiency (%)
		0.05	0.10	0.20	0.25	0.30	0.50	0.75	1.00		
UMPP max	1300	97.52	98.19	98.64	98.69	98.86	98.89	98.81	98.70	98.73	98.79
UMPP	1189	97.86	98.50	98.93	98.95	99.01	98.98	98.91	98.88	98.89	98.92
UDC,r	1080	97.32	98.21	98.38	98.53	98.59	98.61	98.52	98.36	98.47	98.52
UMPP min	930	96.55	97.47	98.06	98.28	98.40	98.53	98.41	98.28	98.28	98.37

5.2 MPPT Algorithm

Another key metric contributing to the inverter energy production is the MPPT efficiency or effectiveness. The MPPT is the algorithm that is implemented in a PV inverter to capture the highest amount of energy possible from the PV array by continuously searching for and operating at the maximum power level supported by the connected modules operating under the given set of conditions at the time of conversion.

The Huawei SUN2000 series utilizes a refined three-step disturbance observation algorithm [36], an enhanced form of the conventional Perturb and Observe (P&O) method. Traditional P&O approaches rely on small voltage perturbations and monitor power changes to determine the correct tracking direction. However, during rapidly changing irradiance, this can lead to false tracking and oscillations around the MPP.

To address these limitations, Huawei's algorithm introduces three sequential stages — Pre-disturbance, Confirmation, and Tracking. The inverter perturbs the voltage in both directions, compares the resulting power differences, and determines the correct adjustment direction based on the averaged response. This method compensates for short-term irradiance fluctuations, reduces oscillations, and ensures faster convergence to the true MPP. A fast open-loop optimization is also performed during startup, allowing the inverter to quickly approach the estimated MPP before engaging in closed-loop tracking. This reduces energy loss during initialization and enhances the inverter's overall tracking efficiency.

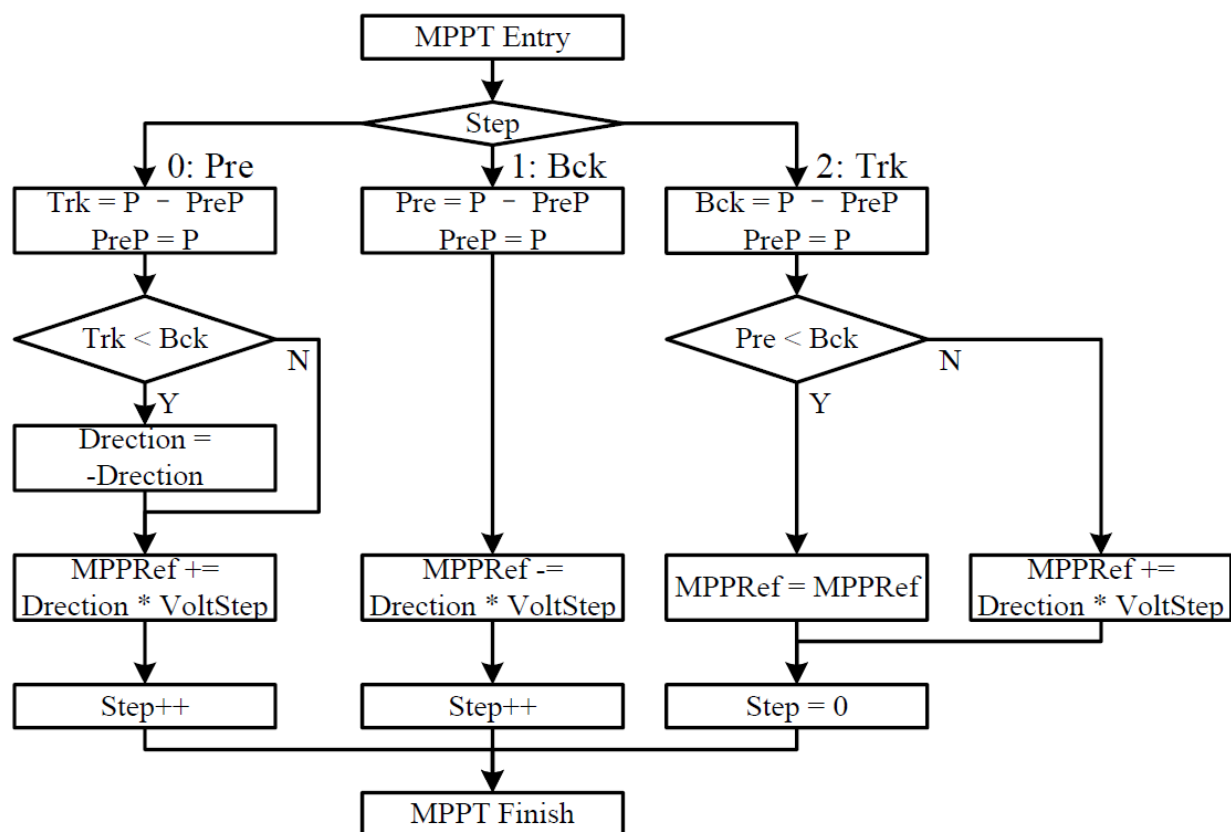


Figure 5-2 MPPT Algorithm flowchart [36]

Through this adaptive three-step method, the inverter achieves a strong balance between response speed, accuracy, and stability, ensuring consistent power generation and high MPPT efficiency under dynamic field conditions. The MPPT algorithm flowchart is shown in Figure 5-2.

MPPT effectiveness is divided into two main components, static and dynamic effectiveness. Static effectiveness refers to the ability of the inverter to accurately operate at the maximum operating point over long periods of time given a set of constant PV characteristics. Dynamic effectiveness refers to the ability of the inverter to respond quickly and accurately to changing irradiance levels.

DNV reviewed the type test results of the Huawei SUN2000-330KTL-H2 inverter's static and dynamic MPPT effectiveness performed by Intertek in accordance with EN 50530 [37]. The Huawei SUN2000-330KTL-H2 MPPT controls demonstrated operation in line with other inverter products, scoring 99.90% to 99.93% efficiency for the static tests, and 98.95% on the overall dynamic tests. See Table 5-3, Table 5-4, and Table 5-5 for test data.

Table 5-3 Static MPPT efficiency results [37]

MPP voltage of the simulated I/U characteristic of the PV generator		MPP power of the simulated I/U characteristic normalised to rated DC power d , $PMPP,PVS/PDC,r$ (%)								European MPPT efficiency (%)	CEC MPPT efficiency (%)
		0.05	0.10	0.20	0.25	0.30	0.50	0.75	1.00		
UMPP _{max}	1300	99.59	99.56	99.77	99.82	99.92	99.93	99.93	99.90	99.87	99.90
UMPP	1189	99.13	99.66	99.83	99.85	99.92	99.93	99.92	99.91	99.87	99.91
UDC,r	1080	99.50	99.72	99.84	99.84	99.86	99.87	99.88	99.92	99.86	99.87
UMPP _{min}	930	99.71	99.83	99.86	99.87	99.93	99.93	99.92	99.91	99.90	99.92

Table 5-4 Dynamic MPPT efficiency results over 10-50% nominal power range [37]

Irradiance 100-500W/m ² (10%-50%P _{DCn})							
# Number	Slope W/m ² /s	Ramp UP s	Dwell time s	Ramp DN s	Dwell time s	Duration s	Dynamic MPPT efficiency- (%)
2	0.5	800	10	800	10	3540	99.8476
2	1	400	10	400	10	1940	99.8340
3	2	200	10	200	10	1560	99.7443
4	3	133	10	133	10	1447	99.6424
6	5	80	10	80	10	1300	99.5124
8	7	57	10	57	10	1374	99.3345
10	10	40	10	40	10	1700	98.9704
10	14	29	10	29	10	1071	98.3360
10	20	20	10	20	10	900	98.0834
10	30	13	10	13	10	767	98.0296
10	50	8	10	8	10	660	96.2104

Table 5-5 Dynamic MPPT efficiency results over 30-100% nominal power range [37]

Irradiance 300-1000W/m ² (30%-100%P _{DCn})							
# Number	Slope W/m ² /s	Ramp UP s	Dwell time s	Ramp DN s	Dwell time s	Duration s	Dynamic MPPT efficiency- (%)
10	10	70	10	70	10	1900	99.7558
10	14	50	10	50	10	1500	99.6707
10	20	35	10	35	10	1200	99.6368
10	30	23	10	23	10	967	99.3439
10	50	14	10	14	10	780	97.6924
10	100	7	10	7	10	640	98.5617

Table 5-6 Start-up and shut-down test with slow ramps [37]

Irradiance 10-100W/m ² (slow ramps)							
# Number	Slope W/m ² /s	Ramp UP s	Dwell time s	Ramp DN s	Dwell time s	Duration s	Dynamic MPPT efficiency-(%)
1	0.1	980	30	980	30	2320	99.6552

Calculation of the dynamic MPPT efficiency

The overall dynamic MPPT efficiency:	98.9533
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5.3 DC-AC ratio (inverter loading ratio)

The Huawei SUN2000-330KTL-H2 inverter datasheet and supporting documentation do not explicitly specify a permissible DC–AC overloading ratio or a maximum allowable DC power (kWp) per inverter. The design limits on the DC side are instead governed by maximum DC voltage (1500 V), MPPT current limits, and number of inputs, as defined in Section 4.3.

The inverter's DC input design supports DC loading operation through:

- Wide MPPT operating voltage range of 500–1500 V, with a full-load MPPT voltage range of 930–1300 V
- Maximum current per MPPT of 65 A and short-circuit current capability of 115 A
- Eight to ten parallel string capability per inverter (28 strings across 6 MPPTs)

5.4 Power- DC Input Voltage Curve

The power-voltage (P_{out} – V_{in}) curve of the Huawei SUN2000-330KTL-H2 inverter as shown in Figure 5-3 illustrates the variation of AC output power with respect to the DC input voltage. As shown, the inverter achieves its rated output (~330 kW) within the nominal operating window between approximately 930 V and 1300 V. Below 930 V, the available AC output power decreases proportionally with the DC input voltage. Beyond 1300 V, the inverter output begins to derate significantly proportional to input voltage, primarily to protect internal components and ensure safe thermal operation.

Based on industry experience and simulation tools, MPP voltages approaching or exceeding ~1300 V can occur under certain operating conditions, particularly during cold and clear weather. While such conditions may not be frequent on an annual basis, they are not negligible and should be considered credible operating scenarios.

Therefore, although operation in the upper voltage range (e.g., >1300 V) may be limited in duration, it cannot be excluded. The system design should ensure adequate voltage margin and compliance with inverter limits (1500 V maximum and MPPT range) to maintain safe and reliable operation under all expected environmental conditions.

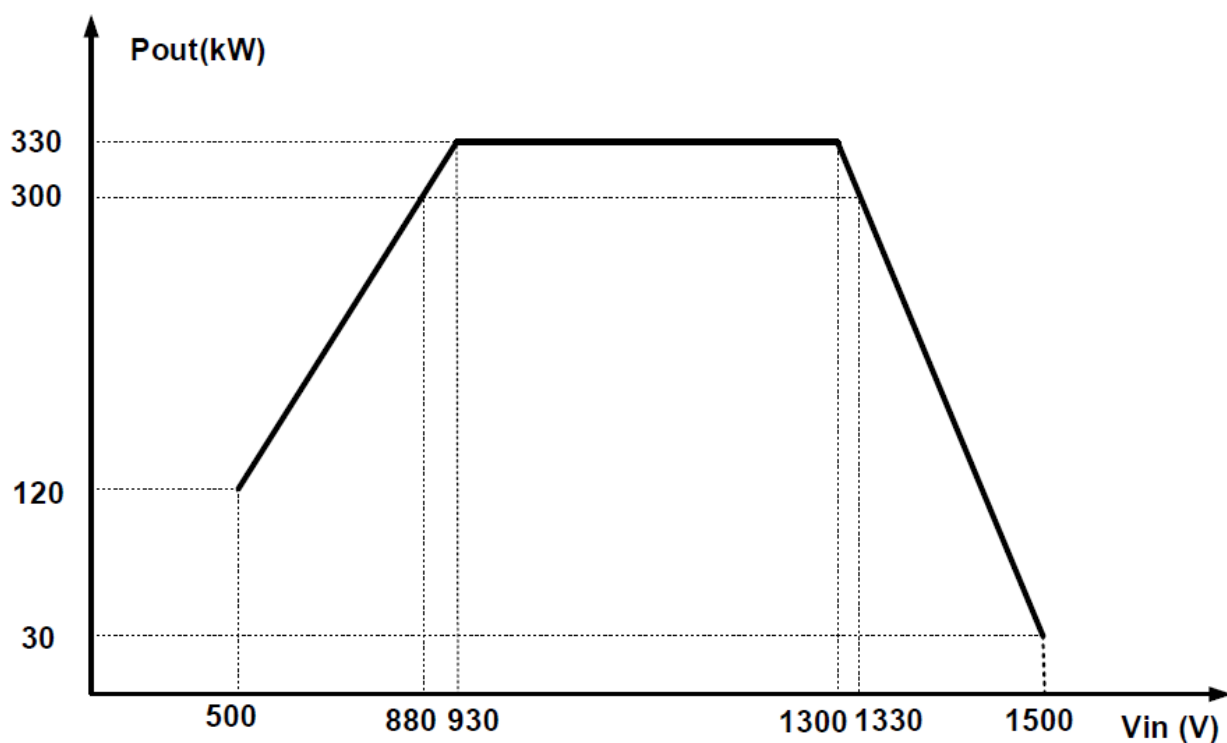


Figure 5-3 Power-DC Input Voltage Curve of Huawei SUN2000-330KTL-H2

5.5 Auxiliary Consumption

As mentioned in the IEC 61683 test report [35], for the Huawei SUN2000-330KTL-H2 inverter, the no-load power loss was approximately 11.1 W (~0.003%), while the standby loss was around 2.7 W (~0.001%). As mentioned in the manual [19] Self-consumption at night (sleep mode) is 4.8W (~0.001%).

These results reflect low auxiliary consumption during non-operational states, highlighting the inverter's efficient control circuitry and optimized internal design, consistent with the emerging high-efficiency string inverters in the market.

6 QUALITY AND RELIABILITY

6.1 Reliability Evaluation

High reliability of PV inverters is critical for the successful operation of PV power plants. Inverter reliability has historically been an issue and is an important focus in the supplier decision making process by PV inverter customers.

DNV views achieving inverter reliability as a set of processes throughout the design and operational lifecycle and encompassing three primary facets for completeness:

- Design for reliability
- Reliability testing
- Field reliability history

6.1.1 Design for Reliability

A number of elements go into design for reliability. These include component selection and de-rating, analytical reliability calculations, and failure mode analysis. Additionally, the Engineering processes used to design a new product provide the control gates necessary to assure that design guidelines are met.

6.1.1.1 Product Development Process

Huawei has adopted Integrated Project Delivery (IPD) approach in product development process. The IPD process consists of six stages: Concept, Plan, Develop, Qualify, Launch, and Lifecycle as shown in Figure 6-1.

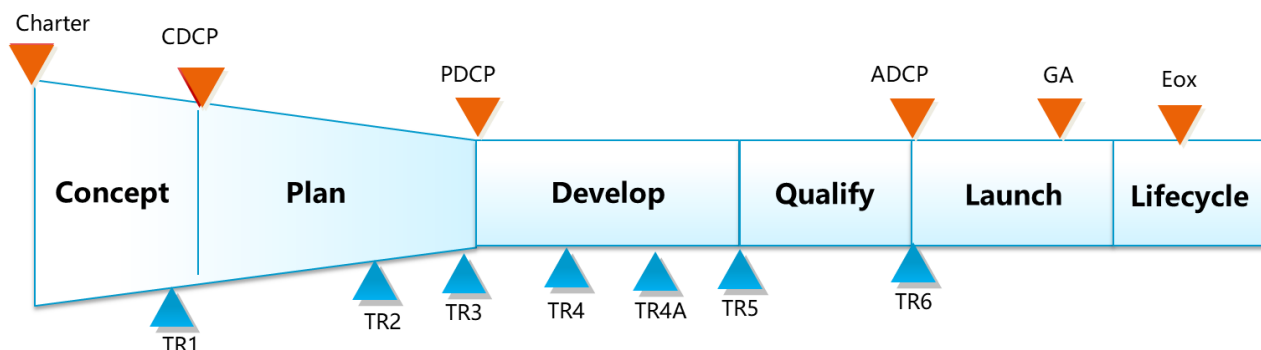


Figure 6-1 Huawei IPD Process Flow

- **Concept Stage:** Preliminary evaluation of market opportunities, requirements, quality, technologies, risks, and cost projections. The PDT (Product Development Team) prepares an initial business plan and project charter.
- **Plan Stage:** Expansion of the business plan into a detailed product definition, including development, manufacturing, marketing, support, and financial plans. Architecture consistency is reviewed for alignment with company standards.
- **Develop Stage:** Execution of detailed design, prototyping, testing, and verification through System Design Verification (SDV) and System Integration Testing (SIT). Also, during this stage, the Manufacturing processes are developed and validated.
- **Qualify Stage:** Final testing and certification, including hardware/software stress tests, standards compliance, and beta validation before mass production.
- **Launch Stage:** Commencement of full-scale production and sales, with gradual capacity ramp-up and transition from development to maintenance.

- Lifecycle Stage: Continuous monitoring, sales, service, and performance management throughout the product's operational lifecycle.

DNV notes that while the product development lifecycle framework defines a structured approach from concept through end-of-life, actual execution outcomes may vary depending on project scope, market dynamics, and resource alignment. Nevertheless, the defined stage-gate process demonstrates Huawei's commitment to systematic product planning, cross-functional coordination, and continuous improvement in design and reliability practices.

6.1.2 Component selection and derating

An important aspect of achieving high product reliability is the selection of quality parts and the design for operation at appropriate stress levels which will allow the components to perform reliably for their expected service life. It is common for electronic product manufacturers to implement in-house design guidelines for the levels of stress at which individual components are allowed to operate. This includes derating factors below the component specification limits for factors such as semiconductor device junction temperature, capacitor ripple current, applied voltage, and ambient temperature. A component's electrical and thermal deratings are calculated by assessing the component's measured values in-use compared to the rated values of the component.

Huawei provided concept of the engineering margin applied to their components. Huawei applies derating specifications to all their components (IGBTs, capacitors, resistors, etc.). Huawei applies different deratings for voltage, current, temperature for all its components. Huawei conceptually defines the rated operating inverter conditions and then based on the occurrence of the different operating states; the derating requirements are defined.

Huawei also provided component level lifetime calculations and design considerations for components [55] such as, capacitors, photocouplers, IGBTs, fan, DC load break switch. Huawei utilizes applicable component level calculation based on its operating experience. Given the criteria assumed by Huawei, the components are required to provide a minimum expected life of 25 years.

In addition to designing for low stress and design margin on components, the individual component selection is critical. One area that can have a significant negative impact on the reliability and lifetime of an inverter product is the use of components with known wear-out mechanisms such as fans and capacitors. The applicable field stress and operating temperatures have a considerable impact on the lifetime of such products.

6.1.3 Mean time between failure (MTBF)

DNV believes that an important analytical approach for evaluating the reliability of a power inverter is to calculate the product Mean Time Between Failure (MTBF). The benefit of an MTBF calculation is the information gained due to a component-by-component review of design margins and expected life. DNV views the calculation of MTBF positively but believes any changes in the design or operation of the inverter as a result of the review represent a higher return from the effort.

Huawei provided DNV with the SUN2000-330KTL-H2 MTBF Prediction Report [54], calculated using the Telcordia SR-332 Issue 3 (Parts Count Method). MTBF value is derived from a component-level reliability model, where the total inverter failure rate is calculated as the aggregation of individual component failure rates (e.g., IGBTs, capacitors, resistors, relays, control boards, sensors, and connectors). The MTBF calculation considers component-level stress factors such as temperature (πT), voltage (πS), environment (πE), quality (πQ), and operating time (πH). The reference temperature and electrical stress vary between different components based on their operational requirements. Typically, the default electrical stress considered is 50% and temperature considered is 40°C. The summary of analysis is shown in Table 6-1. This analysis reflects an extensive breakdown across discrete components, including resistors, capacitors, relays, power semiconductors, and sensors.

Table 6-1 Summary of Key MTBF Data (Huawei SUN2000-330KTL-H2)

Parameter	Description / Value
Standard Used	Telcordia SR-332 Issue 3 (Parts Count Method)
Applicable Models	Huawei SUN2000-330KTL-H2
Total Number of Components	3,944
Total Failure Rate (APC)	253,578 FITs (Failures per 10 ⁹ hours)
Calculated MTBF	3.94 × 10 ⁶ hours (~450 years considering 24 hours operation)
Reference Temperature	40°C (nominal), average ambient 25°C
Main Stress Factors	Temperature (πT), Voltage (πS), Environment (πE), Quality (πQ), Operating Time (πH)
Standard Used	Telcordia SR-332 Issue 3 (Parts Count Method)

The referenced “failures” correspond to statistical failure probabilities of individual components, rather than direct field-observed failures of the inverter as a complete system. The resulting MTBF represents a theoretical reliability indicator under assumed operating conditions, not a guaranteed service life of the inverter. At present, no separate system-level MTBF study for the complete inverter unit has been provided. In industry practice, such system-level reliability is typically validated through a combination of field performance data, failure rate statistics (fleet data), and warranty/availability records, rather than purely analytical models.

DNV views the provision of component-level MTBF analysis positively as it demonstrates a structured reliability assessment approach. However, for enhanced confidence in such theoretical estimates, it should be complemented with operational track record and fleet reliability data to better represent the expected performance of the inverter at system level.

6.2 Product Reliability Testing

A second critical area for validating and estimating product reliability includes the testing of the components, subsystems and final assembly of the inverter products. This section of the report highlights the data provided to DNV in regard to this topic.

Huawei has an extensive set of reliability testing laboratories known as the Huawei Global Reliability Center. Inside these facilities there are a host of environmental chambers for thermal cycling, damp heat, ultraviolet, humidity freeze, dust, salt fog and other testing needs. The facilities are shared across multiple product lines but highlight product reliability testing capabilities in-house.

Huawei has established internal test procedures [56] that must be completed before the commercial production of any new product. These procedures are intended to verify the design through a series of environmental and reliability tests and define the required test scope, methods, and sample requirements. The typical qualification program includes environmental adaptability testing (4K4H, refer Section 6.2.2), Highly Accelerated Life Testing (HALT) (refer Section 6.2.3), and durability testing (refer Section 6.2.3).

Component Highly Accelerated Life Testing (HALT) is performed once prior to the commercial production of a new inverter type to verify component specifications and assess long-term performance. DNV was provided with a summary test report [57] covering board-level component testing conducted before the launch of one Huawei product. However, HALT testing is not repeated for components after product launch. Instead, Huawei conducts production-line reliability tests such as High Temperature Operating Life (HTOL), based on random selection of inverter units representing 1% of each production lot

6.2.1 Design Verification Testing (DVT)

A design verification test (DVT) is typically written to verify the basic functions of an inverter, such as checking power supply voltages and testing communications channels.

The IEC 62109, IEEE 1547 and other grid code test reports were reviewed by DNV as a form of design verification testing. The tests are extensive, demonstrating both product safety and inverter functionality.

6.2.2 Environmental testing

The Huawei SUN2000 series (rated from 275 kW – 330 kW) string inverters have undergone environmental testing in accordance with the IEC 60721-3-4 classification [21], in their testing laboratories. This test represents different environmental categories and severities for outdoor electrical equipment. This testing confirms the inverter's ability to maintain reliable operation under different climatic and mechanical conditions typically encountered in utility-scale solar installations. The test regimen included prolonged exposure to high and low temperatures, humidity cycling, mechanical vibration, shock, salt mist corrosion, and ingress protection validation. Total of seven samples were tested in this test. In Table 6-2, the different test and the test parameters are provided.

Table 6-2 IEC 60721-3-4 4K4H test result of SUN2000-185KTL-H1

Sr. No.	Test Item	Standard Compliance	Test Parameter	Result
1	Low temperature storage	IEC 60068-2-1: 2007	-40°C, 24h	Pass
2	High temperature storage	IEC 60068-2-2: 2007	+70°C, 24h	Pass
3	Damp heat steady state storage	IEC60068-2-78: 2012	+60°C, 95%RH, 96h	Pass
4	Low temperature operation	IEC 60068-2-1: 2007	-25°C, 24h	Pass
5	High temperature operation	IEC 60068-2-2: 2007	+60°C, 24h	Pass
6	Temperature cycle operation	IEC 60068-2-14: 2009	-25°C to +60°C, 1°C/min, 3h soaked at each extreme temperature, 2 cycles	Pass
7	Damp heat steady state operation	IEC60068-2-78: 2012	+60°C, 95%RH, 96h	Pass
8	Damp heat cyclic operation	IEC 60068-2-30: 2005	+25°C~+60°C,95%, 48h	Pass
9	Sinusoidal vibration operation (Test sample: package)	IEC 60068-2-6: 2007	5 Hz to 9 Hz, Amplitude: 1.2 mm (O-P) 9 Hz to 200 Hz, Acceleration: 1 g 1oct/min, 3 axes, 5sweep cycles per axis	Pass
10	Sinusoidal vibration operation (Test sample: product)	IEC 60068-2-6: 2007	5 Hz to 9 Hz, Amplitude: 1.2 mm (O-P) 9 Hz to 200 Hz, Acceleration: 0.4 g 1oct/min, 3 axes, 5sweep cycles per axis	Pass
11	Random Vibration operation	IEC 60068-2-64: 2008	10Hz to 100Hz, Grms: 0.5 30min/ axis, 3 axes,	Pass
12	Shock operation	IEC 60068-2-27: 2008	Half sine, 11ms, 50m/s ² , 3 axes, 6 times per axis	Pass
13	IP66	IEC60529:2001	IP66	Pass
14	Salty Test	IEC 60068-2-11	28 days	Pass
15	Acoustic test	NB/T 32004	Measurement surface,75dB(A);	Pass

Across all test phases, the inverters maintained stable output, showed no fault alarms, and exhibited no physical or electrical degradation. The successful completion of the tests demonstrates that Huawei SUN2000 inverters are engineered to operate in demanding climatic conditions.

6.2.3 Highly Accelerated life testing (HALT)

HALT is a method of testing electronic equipment in a relatively short amount of time to determine that it will have reliable performance over its expected operating life. This is done using test chambers and techniques to apply stress on the components that are beyond those that it is expected to normally encounter. This typically includes high and low temperatures, temperature ramping, and vibration. The equipment is exposed to high levels of stress and then issues are addressed as they are found. DNV believes that HALT testing is a critical part of the development process for a highly reliable product.

DNV was provided with HALT test report for inverter model SUN2000-185KTL-H1by Huawei [38]. The HALT methodology and test configuration for the SUN2000-185KTL-H1 inverter—belonging to the same product series as the SUN2000-330KTL-H2—were reviewed as part of this assessment. Testing demonstrated stable inverter operation

across the full applied stress spectrum, with no critical, major, or minor defects observed. The inverter successfully passed all stages, maintaining output up to the defined stress limits.

Table 6-3 HALT test result of SUN2000-185KTL-H1

Stress Condition	Range	Result
Low Temperature Step	–10 °C to –55 °C	Pass
High Temperature Step	+60 °C to +100 °C	Pass
Vibration Step	10 G to 40 G	Pass
Combined Stress	–43 °C to +85 °C / 40 G	Pass

Although the above HALT results refer specifically to the SUN2000-185KTL-H1 model, both inverters share a similar hardware and control architecture within Huawei’s SUN2000 series. It is therefore reasonable to infer comparable reliability and stress tolerance for the SUN2000-330KTL-H2. Results are indicative and are not directly transferable to SUN2000-330KTL-H2. Formal testing or manufacturer confirmation would be required to establish exact reliability margins for the 330kW variant.

6.2.4 Reliability and Durability Testing

Durability testing was performed on SUN 2000 inverters series. DNV was provided with summary of the results, where in four units were tested for temperature cycle & high humidity storage, temperature cycling & long-term service life in humidity and heat, high temperature operation lifetime (HTOL) and HTOL long service life. Table 6-4 presents the tests performed, the hours and boundary conditions applied, with the results of the tests. Huawei provided the report results, as evidence of testing; however, a summary document that details the verification of all features and specifications was not provided for review.

Overall, the testing evaluation demonstrates Huawei’s systematic approach to accelerated reliability verification. The test methodology effectively identifies design vulnerabilities early in the product development cycle, supporting continuous improvement in thermal, mechanical, and electronic durability but lacks long-term durability verification. DNV views, this overall testing program from Huawei positively.

Table 6-4 Reliability HALT test result of SUN2000 inverters

Test and Verification Items					Test sample and test result			
Test Item	Test sub-item	Test Category	Test conditions		Prototype 1	Prototype 2	Prototype 3	Prototype 4
Reliability test	Temperature cycle & high humidity storage	Temperature cycle & high humidity storage	(−40°C to 70°C temperature cycle, 70°C 85% RH humid heat storage for 240 hours)		PASS	NA	NA	NA
	Temperature cycling & long-term service life in humidity and heat	Temperature cycling & long-term service life in humidity and heat	(−40°C to 70°C: 1500 cycles; 70°C: 85% RH: 1000 hours)		NA	PASS	NA	NA
	HTOL	High Temperature Operation Lifetime	Aging running for 1000 hours		NA	NA	PASS	NA
	HTOL long service life	HTOL long service life	Aging running for 2000 hours		NA	NA	NA	PASS
Function test after reliability	System black box-level review	observation of analog parameter	Test the sampling precision of the voltage, current, and power.		NA	PASS	NA	PASS
White box test after reliability	Appearance inspection	External of the entire system	External structure power distribution	Overall Appearance Check	PASS	PASS	PASS	PASS
				Switches and Connectors Inspection	PASS	PASS	PASS	PASS
				AC and DC cables	PASS	PASS	PASS	PASS
		Inside the entire system	Internal structure power distribution	Use vernier calipers to measure the bending height of the three-phase AC rigid copper bar on the board.	PASS	PASS	PASS	PASS
				Connector review	PASS	PASS	PASS	PASS
				Cables and fastening screws are reviewed. Torque wrench is required.	PASS	PASS	PASS	PASS
				Overall review within the entire system	PASS	PASS	PASS	PASS
				Radiator and Heat Exchanger Review	PASS	PASS	PASS	PASS
				Silicone Grease Review	PASS	PASS	PASS	PASS
				Insulation paper review	PASS	PASS	PASS	PASS
			Board	Check the component falling off and foreign matter.	PASS	PASS	PASS	PASS
				Check the fixed white adhesive.	PASS	PASS	PASS	PASS

				Appearance of PCB coating and cabling	PASS	PASS	PASS	PASS
				Inspection of PCB solder joints with large through-current	PASS	PASS	PASS	PASS
	Hardware white box	Capacitance measurement on board	Measure the total capacitance of the boost input capacitor on the board.	Measurement of the Total Capacitance of Each Boost Input Capacitance	PASS	PASS	PASS	PASS
			Total capacitance of flying capacitor measured on board	The total capacitance of each flying capacitor is measured on the board.	PASS	PASS	PASS	PASS
			bus electrolytic capacitor	Total capacity of bus electrolytic capacitor	PASS	PASS	PASS	PASS
			bus thin film capacitor	Total capacity of busbar film capacitor	PASS	PASS	PASS	PASS
			INV AC thin film capacitor	Total capacitance between A and B, AC, and BC	PASS	PASS	PASS	PASS
		Key component measurement	IGBT module	Parameter measurement and DPA analysis	PASS	PASS	PASS	PASS
			power inductor	Inductance and inductance measurement	PASS	PASS	PASS	PASS
			Capacitance	Capacitance and DF measurement	PASS	PASS	PASS	PASS
			Fan	Speed test for internal fans, external fans, and dehumidifier fans	PASS	PASS	PASS	PASS
			On-board switch and PV terminal and grid-tied relay through resistance	Pin On Resistance Measurement	PASS	PASS	PASS	PASS
		Auxiliary source test	AC/DC auxiliary power source and 60 W auxiliary power source test	Three-temperature ripple precision, power-on and power-off overshoot, and dynamic load test	NA	PASS	PASS	NA
	Board/Component DPA	/	/	/	PASS	PASS	PASS	PASS

6.2.5 Test during production

All inverters manufactured by Huawei are subjected to a series of factory acceptance tests prior to shipment (refer for the typical in line factory testing). Test equipment is along a transportation line connecting directly with the inverter assembly line. Hence, all of the tests are conducted along the line without any carrying of inverters. Highlights of the testing include visual inspection, functional test, waterproof test, insulation test, voltage withstand test, mechanical operation, electrical operation, anti-islanding, grid reconnection, continuous aging (burn-in) test etc. DNV was provided with an in-line record for these inverter tests [17]. Burn in test is performed at full power for at least 4 hours at 50°C.

DNV views the production tests as typical, except for burn-in. The burn-in test is sometimes performed on sampling basis and not on 100% produced units. DNV notes that it finds burn in test very useful in reducing manufacturing variations in the product and reducing the infant mortality related failure rates. DNV views Huawei use of burn-in positively.

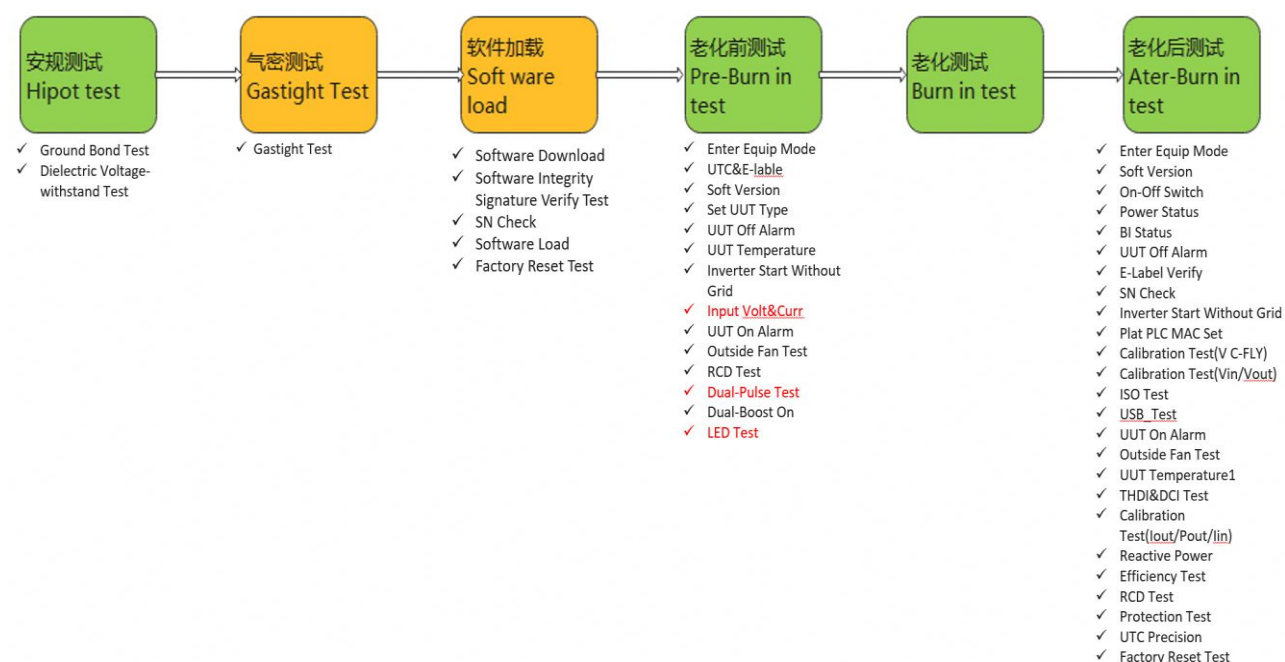


Figure 6-2 Typical Inverter in line production tests



Figure 6-3 Inverter testing in line

6.2.6 Field reliability history

DNV considers demonstrated field history to be one of the most critical elements in the review of an inverter product. When proper field history data is available, consideration is given to the size of the population, the duration of time in operation, number of and type of field failures, and the processes utilized by a manufacturer to document and learn from such events.

A study of field reliability is an important step in determining the estimated inverter life. Previous inverter experience may provide insight into future reliability. A strong track record for introducing inverters into the field provides a foundation from which new inverters can be studied.

For field performance, DNV acknowledges two time periods that give insight into reliability. After one year of field operation for a significant population, issues of infant mortality and early latent defects should have been discovered and addressed. Early inverter reliability tends to foretell long-term reliability, in that a well-engineered and well-manufactured inverter that is reliable in the short term tends to last longer.

The second significant anniversary is year 3, after which the inverters have usually operated in multiple locations, typically causing site and grid related issues to become apparent. Inverters during the 3-year period are generally subjected to only forms of random failures. Failures due to component wear-out or aging generally do not appear within the 3-year period.

Huawei provided operational data for 300 KTL inverters installed across nine projects in China, representing an accumulated capacity of approximately 13.8 GW. The projects were commissioned between Q3 2023 and Q1 2025. Based on roughly 15 months of operational data from 2025 and 2026, Huawei reported an accumulated inverter failure rate of 0.68%.

The inverter under review demonstrated typical inverter reliability in the first years of operation. Most inverters demonstrated the typical initial field reliability represented by the “bathtub curve” with reliability improving after an initial period of infant mortality.

Huawei studies early, mid, and long-term failure rates to separate infant mortality issues from mid-term reliability, and long-term failure rates, which eventually may signal end-of-life.

Huawei uses a dedicated software platform to collect customer service requests, Huawei’s responses, and the associated inverter failure data. When an inverter failure occurs, the system generates a report and automatically notifies the R&D team. Huawei service engineers typically classify each failure within the platform into four main categories: software-related issues, hardware-related issues, operation outside specified limits, or incorrect documentation

DNV considers the platform suitable for processing service requests and identifying failure trends. This provides an effective feedback loop for the product development team and supports continuous design improvement. DNV views this process positively. Through this mechanism, Huawei’s R&D team has developed inverter failure rate statistics across its inverter models, which are used to update current and future product designs.

7 REGULATORY AND STANDARDS EVALUATION

This section describes the standards to which the SUN2000-330KTL-H2 inverters are certified and the regulations which they must comply with.

DNV notes that leading Chinese inverter manufacturers continue to demonstrate a substantial global operational track record, and financial strength. Although there are currently no specific regulatory restrictions on Chinese inverters in the Middle East, emerging regulatory scrutiny and cybersecurity-related developments in Europe and the United States introduce a material non-technical bankability risk that lenders and investors should continue to monitor.

7.1 Applicable Standards

Compliance with both international and regional standards is fundamental to guaranteeing the safety, reliability, and grid integration of PV inverters deployed in the GCC market.

Table 7-1 outlines the principal standards applicable to inverter certification, highlighting their role and relevance. While global benchmarks such as IEC 62109, IEC 61000, and IEC 62116 establish the framework for safety, EMC, and grid interaction, local utility authorities additionally require grid-code conformity certificates (e.g., SEC in Saudi Arabia, DEWA in Dubai, EWEC in Abu Dhabi, KAHRAMAA in Qatar). Collectively, Together, these standards establish the framework for verifying inverter compliance, operational performance, and applicability in the challenging conditions of the region.

Huawei has developed the inverter in accordance with the requirements of multiple international standards organizations, including IEC, EN & IEEE. DNV considers this global compliance approach to be a strong indicator of product maturity and adaptability across different grid environments.

The SUN2000-330KTL-H2 inverter has been tested and certified to meet a broad range of IEC and regional grid standards, as summarized in the Table 7-1. Compliance with different grid codes is covered in the section 4.3.3.7. Compliance testing and certification were carried out by internationally recognized independent laboratories such as TÜV SÜD and Intertek, both of which are accredited and reputable Nationally Recognized Testing Laboratories (NRTL). Summaries of the associated test reports and certificates are provided in the appendices of this report.

Table 7-1 Applicable Standards for Inverter in GCC markets.

Standard	Definition
Type Testing & Grid Compliance	
IEC 62109 series [40]	Safety of PV inverters (protection against electric shock, fire, thermal hazards). Widely accepted in GCC; DEWA accepts UL 1741 as an alternative.
IEC 61000 (all applicable parts) [41]	Electromagnetic compatibility (EMC): limits for emissions, immunity to disturbances, and harmonic current requirements. Includes IEC 61000-3-2/-3-12 (harmonics) and IEC 61000-6-x (industrial/residential).
IEC 62116 [45]	Test procedure for anti-islanding protection. Required by GCC utilities such as SEC (Saudi) and DEWA (UAE).
IEC 61727 [43]	Utility interface standard for PV inverters (voltage/frequency operating window, power quality, and protection functions).
Grid compliance test report / certifications [30][31][32][33][34]	Mandatory proof of compliance with local GCC grid codes (e.g., SEC, DEWA, KAHRAMAA, APSR, EWA, DOE). Covers ride-through, reactive support, Rate of Change of Frequency (RoCoF), etc. covered in section 4.3.3.7
IEC TS 62910	Test procedure for undervoltage ride-through (LVRT/UVRT). Supports compliance with GCC grid codes.

Standard	Definition
IEC TS 63217	Test procedure for overvoltage ride-through (OVRT). Ensures inverter capability to withstand voltage disturbances.
Performance and Environmental Test Standards	
IEC 60068-2 [42]	Environmental testing (temperature, humidity, vibration, salt mist). Demonstrates inverter reliability under harsh GCC conditions.
IEEE 1547 [44]	U.S. grid interconnection standard (islanding, ride-through, voltage/frequency response, reactive power). Not mandatory in GCC but often accepted as supporting evidence.
IEC 62920 [46]	EMC requirements tailored for PV power conversion equipment (beyond general IEC 61000 standards).
IEC 60529 [50]	Ingress protection (IP rating). Verifies dust/water sealing. Critical for desert/outdoor GCC environments.
IEC TS 63156	Standardized procedure for evaluating inverter conversion efficiency and performance.
IEC TS 63157	Quality assurance (QA) guidelines for PV power conversion equipment manufacturing.
IEC 62477-1	Safety requirements for power electronic converter systems (PECS). Complements IEC 62109.
EN 50530 [37] / IEC 61683 [35]	Overall efficiency of grid connected photovoltaic inverters
Conformity Certificate (CE) [49]	CE is often accepted as supporting evidence of product quality and safety, especially in consultant reviews, tenders, and EPC procurement.
Not Typically Applicable / Conditional	
IEC 62093* [47]	Design qualification/type approval for BOS components. Not inverter-specific but sometimes requested at system level.

* Documentation received proves that the test is in progress

7.2 Installation and Maintenance Manuals

DNV reviewed the SUN2000 Series User Manual (Issue 17, ~127 pages) [20] and the Quick Installation Guide (~74 pages) [51] provided by Huawei for the SUN2000-330KTL-H2 inverter.

The User Manual [20] provides a comprehensive description of the inverter, covering key aspects such as safety requirements, storage and handling conditions, installation procedures, electrical connections, commissioning, operation, maintenance, troubleshooting, and alarm handling. The document is structured in a logical sequence, starting from safety and environmental requirements through installation and commissioning, and extending to detailed maintenance procedures and fault diagnostics.

The manual includes detailed guidance on:

- Site selection, environmental and clearance requirements
- Mechanical installation and mounting configurations
- DC/AC cabling, grounding, and communication interfaces
- Commissioning procedures via SmartLogger and mobile applications
- Routine and corrective maintenance activities (e.g., fan replacement, fault isolation)
- Alarm reference and troubleshooting workflows

The Quick Installation Guide [51] complements the main manual by providing concise, step-by-step visual instructions for installation, cabling, and commissioning, supported by clear diagrams and safety notes. It emphasizes critical

installation practices such as proper cable preparation, grounding, and AC/DC connections, and highlights that non-compliance with installation and handling guidelines may void warranty coverage.

DNV considers the provided installation and maintenance documentation to be complete and of good technical quality, adequately supporting safe installation, operation, and maintenance of the inverter. The availability of both detailed manuals and simplified quick guides is viewed positively, as it ensures usability across different stages of project execution.

8 INVERTER WARRANTY AND SUPPORT

8.1 Service Warranty Evaluation

Huawei provides a standard 5-year warranty for its utility-scale Smart PV inverters, including the SUN2000-330KTL-H2 model [50]. The warranty period commences either 90 days from the shipment date or from the proof of delivery (POD) date, whichever occurs first. The coverage applies within the country of purchase and is non-transferable unless formally approved by Huawei.

The warranty covers the hardware and software of the inverter as a complete product and includes:

- Remote technical support, troubleshooting, and software update guidance available 24/7 online or during standard business hours (9am-6pm on working days, response within 30 minutes outside China)
- Replacement of defective units or spare parts, either through local warehouse stock or via shipment from Huawei's global supply hubs, depending on local logistics conditions.
- Functional equivalence assurance, ensuring that replacement equipment is of equal or better performance and may be either new or refurbished.

Customers are required to return defective units within 15 business days after receiving the replacement. Huawei bears the transportation cost for returning defective units during the warranty period, provided the defect is confirmed and the replacement process is approved. However, if returned parts are found not to be faulty or claims are not validated, the Buyer may be required to bear the associated transportation costs.

The extended warranty can be purchased in successive terms prior to the expiry of the standard coverage, allowing protection of up to 20–25 years, depending on operational and environmental conditions. DNV views the availability of a 25-year warranty as a positive indication of Huawei's confidence in the reliability of their inverters.

The warranty excludes damage arising from improper installation, non-compliance with operating instructions, unauthorized repairs, inadequate ventilation, lightning events due to poor system design, or normal wear and tear. Huawei's total liability under the warranty is limited to the original product purchase value. These exclusions are considered broadly in line with industry practice; however, the warranty also includes additional clauses such as improper transportation, storage, operation outside specified environmental/electrical limits, use of non-compliant connectors, delayed corrective actions, and third-party unauthorized interventions, which represent typical but relatively comprehensive exclusion conditions.

Normal wear and tears are explicitly classified as degradation or damage arising from natural aging of components over time and is excluded from warranty coverage, consistent with industry practice for power electronic equipment. The warranty is conditional upon proper installation, commissioning, operation, and maintenance of the inverter in accordance with Huawei's official product documentation, including installation manuals, user manuals, and technical guidelines. While on-site commissioning by Huawei is not mandatory, failure to comply with prescribed procedures or use of unauthorized personnel may void warranty claims.

DNV notes that the 5-year period is standard term, with options for progressive extensions, aligns with market norms for utility-scale string inverters.

8.2 Service Infrastructure Evaluation

Huawei's solar inverter service infrastructure is based on a centralized digital service architecture, combining a global remote support platform (FusionSolar and eCare), structured ticketing system, AI-enabled monitoring with regionally distributed spare parts logistics and partner networks. Huawei provided the data in Figure 8-1 that indicates the extent of their general field service capabilities in the UAE.

Local Service Platform, Robust and Reliable onsite service



- **4 Offices:** Dubai, Abu Dhabi
- **800 +** professional engineers
- **300** Service Partners
- **3 Layers TAC center**, 14 Languages – Arabic, English, etc.
- **25 Years** of Service Platform, from 2000

Figure 8-1 Local Service in UAE

For support of the warranty services for SUN2000 products, Huawei has defined an organizational framework to support the process as depicted below:

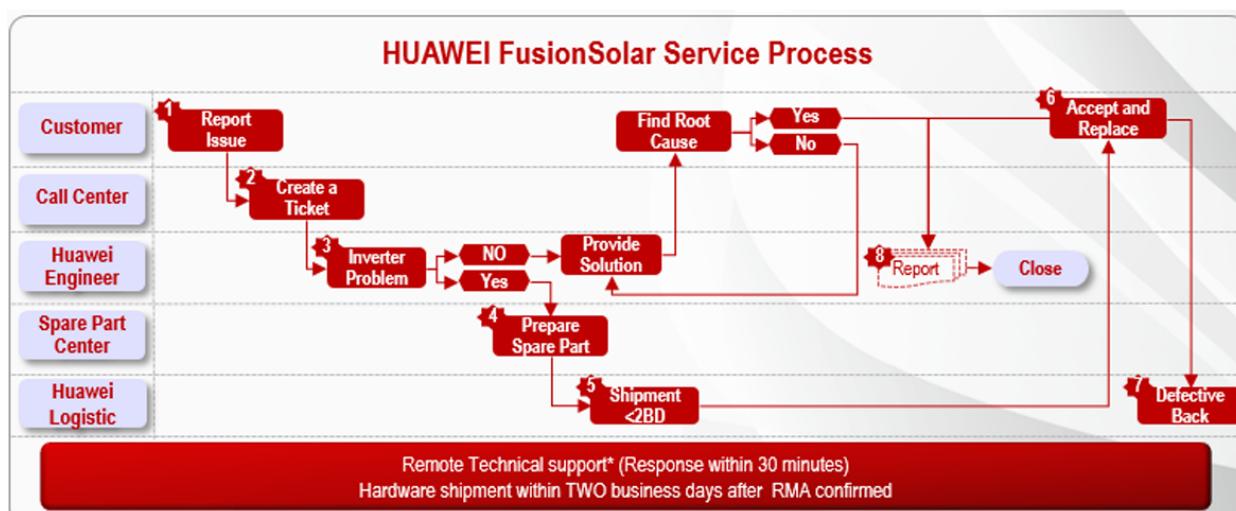


Figure 8-2 Huawei FusionSolar Service Process

The service model prioritizes remote diagnostics, troubleshooting, and software-driven maintenance, supported by 24/7 help desk services, structured SLAs, and continuous software lifecycle management. Hardware intervention is handled through an advanced spare parts replacement model, typically within defined timelines (e.g., 2 business days).

This approach provides scalable, fast, and efficient O&M; however, it depends on reliable communication systems, active customer involvement, and strong local service partners, and therefore needs to be evaluated.

8.3 Workshop repairs

Huawei reports that the string inverters can be repaired in a service depot. The depot repair and return to service of string inverters will change the cost of future repairs, based on the failure modes and Huawei's repair pricing.

In many ways, performing depot repair of string inverters is much like the maintenance strategy for central inverters, which is reasonable, since as string inverters grow in size, and the investment per inverter increases, then options for repair and refurbishment become more viable. With the ability to repair, useful life ends when it is no longer economically prudent to repair the inverters. As with central inverters, the end of useful life is then determined by the frequency of failures and the cost of repair.

With depot repair, the extent to which the inverter owner benefits from this lower cost repair option becomes important. DNV has not performed studies to compare the in-field repair of central inverters, to the in-depot repair of string inverters, however, there will be benefits from performing depot repairs in a clean, controlled environment, with the capabilities and resources not necessarily available for in-field repairs.

Currently, Huawei's depot repair efforts apply largely to equipment still under warranty, for limited locations and with planning underway for the depot repair/refurbishment of out-of-warranty equipment.

9 INVERTER RELIABILITY PREDICTION BY HUAWEI

A common approach used by PV inverter manufacturers to estimate and improve reliability is to identify the expected reliability, and failure rates, of critical components in each product. The preferred method is to incorporate supplier data on reliability with actual field experience to determine the dominant aging mechanisms. Aging mechanisms can be used to inform appropriate accelerated life tests. This approach is called a “physics-of-failure” type analysis in which, if the testing continues until failure, the tests should provide data regarding when component failure will occur due to these applied stresses.

Huawei states that the target design life for their PV solar string inverter products is 25 years, and components are specified and verified through testing to meet this requirement. Huawei does not anticipate any accelerating failure rates within a 20-year useful life period and marks the end of useful life to occur when the annual failure rate reaches 10%.

To gain an understanding of the inverter life, Huawei provided detailed results of their calculations and testing to DNV for review. Individual components are evaluated using the appropriate measures of product life specific to each component. Additionally, Huawei has performed environmental adaptability testing (4K4H, refer Section 6.2.2), HALT (refer Section 6.2.3), and durability testing (refer Section 6.2.4) of the inverters before commercial production. Overall, the product reliability testing demonstrates Huawei’s systematic approach to accelerated reliability verification. The test methodology effectively identifies design vulnerabilities early in the product development cycle, supporting continuous improvement in thermal, mechanical, and electronic durability.

DNV finds that the Huawei accelerated test program provides meaningful data regarding inverter life. However, DNV notes that confidence would increase with a larger number of sample units tested for a longer period of time, with tests performed until component failure. DNV notes that most suppliers make compromises in the number of samples or duration, as fully exhaustive test regimes can become prohibitively expensive and time-consuming. DNV considers the compromises made by Huawei to be consistent with that of competitive products.

Anticipating how the inverters will age, and eventually fail, is part of understanding product life. The accelerated tests performed by Huawei were intended to statistically support an inverter design life of greater than 25 years, with end-of-life due to component wear-out, or due to the accumulation of steady-state failures. However, the 25-year representation is currently beyond the industry-accepted, typical range for string PV inverters. Such a representation will require extensive accelerated test results to substantiate, and thermal acceleration of product life is the widely accepted method.

DNV finds the many extreme-condition tests performed by Huawei to be appropriate and good indicators of the inverter’s abilities to operate in demanding environments under stresses of high and low temperature, high humidity, and with the presence of rain and salt-laden air. These tests are appropriate for validating that the inverters should perform as expected.

Huawei’s string inverters, like most inverters, are subject to risks associated with several factors. Relative to the discussion of reliability, these risks are generally exceptions to the assumptions applied when estimating inverter life. Notable exceptions that generally put inverters at risk include:

- Component design margins applied to the selection of components may not provide wider boundaries against operation outside of the typical operational limits, and therefore the inverter is subject to failure during unanticipated modes of operation or periods of unanticipated stress.
 - For the components reviewed by DNV, Huawei applied appropriate design margins and demonstrated through testing that the inverters can operate at temperatures above the specified limit of 50°C, while power-limiting is necessary to protect the inverter.

- Some site conditions cannot be fully replicated under laboratory conditions, which may lead to unanticipated field operation and potential failures in service. HALT and other qualification tests are generally performed at rated operating conditions—such as rated input voltage, rated output power (or derated power levels)—or at no load while environmental stresses are applied. As a result, these tests may not fully capture the range of combined operational and environmental stresses experienced in actual project environments.
 - The variety of accelerated tests performed by Huawei was intended to stress the inverters beyond the various conditions that will be encountered in the field. DNV finds the testing extensive, while cautioning that some field conditions simply cannot be anticipated in the lab, and are often encountered for the first time in the field.
- In addition to site conditions, inverter design and installation practices are critical factors influencing useful life. In the current market environment, system designs are often optimized close to component performance limits to reduce overall cost. At the same time, inverter design and manufacturing have become increasingly standardized to improve production efficiency and lower manufacturing costs. Consequently, project-specific design choices and installation quality can have a significant impact on inverter operating life and long-term reliability.
- Field data are not yet available for an adequate time across the full fleet of deployed inverters to determine whether the inverters under review are subject to infant mortality effects and/or unexpected operational modes leading to failure.
 - Field data provided by Huawei for the SUN2000-330KT inverters were for a period of much shorter than the three (3) years preferred. Future reviews by DNV will be updated as more data become available to reflect additional information.

The typical expected useful life of string inverters in the industry is generally in the range of 10 to 16 years. Huawei's projected useful life of 20 years for its string inverter is therefore at the upper end of industry-accepted projections for string inverter.

9.1.1 Considerations for longer useful life

Environmental conditions such as dust, humidity, corrosion, rain, snow, and solar exposure can significantly affect inverter durability. In particular, string inverters rely primarily on the enclosure for component protection and therefore benefit from additional environmental shielding, such as installation under an open-air shed, as recommended in Huawei's installation manual. Protection from direct weather and sunlight can extend seal life, reduce the risk of water ingress, and limit cabinet temperature rise due to solar heat gain. Installation inside buildings or under protective covers can further reduce environmental stress, provided adequate ventilation is maintained to avoid additional heating. For demanding environments, corrosion-resistant and well-sealed enclosures, such as stainless steel or painted aluminum cabinets, are expected to improve inverter life.

Effective O&M practices—including regular inspection, cleaning, fan maintenance, and timely software updates—also play an important role in sustaining performance and reducing premature failures. In addition, grid conditions and operational profiles, including voltage fluctuations, cycling behavior, ambient temperature, and average loading, contribute to inverter ageing. DNV considers that the combination of robust enclosure design, reliable components, demonstrated temperature margin, reduced loading during high-temperature operation, and installation practices that provide improved environmental protection can materially enhance inverter useful life, supporting the potential for up to 20 years of useful life.

9.1.2 Inverter life limitations

As discussed in previous sections, longer test periods with more units under test are preferred by DNV. In order to support a life projection of up to 20 years of useful life, DNV recommends thermally accelerated life testing where the hours under test greatly exceed the expected product life, on an accelerated basis. DNV also recommends a test to failure, with a sample size large enough to rule out low occurrence defects. DNV is of the opinion that these enhanced accelerated testing requirements must be applied where extensive field performance data for the model under review are not available.

Future inverter versions may perform differently depending on their specific design. The accumulation of more field data showing good reliability, and more accelerated test results indicating long inverter life, will help industry to gain greater confidence in the design of Huawei inverters. These conclusions reflect the expectation that, going forward, there are no significant changes to these products and that there are no serial defects. (There was no evidence of this presented by Huawei for the SUN2000 inverter series, at the time of this Report). The term “serial defect” pertains to a defect present in many units which is generally related to the design, a component issue, or the manufacturing process. Such defects can largely be prevented by using a thorough and extensive design verification process and component screening. The projection of annual failures does anticipate one or more components eventually wearing out, rapidly impacting the population.

The useful life projection represents an inverter life scenario where the steady-state failure rate is typical for the industry, followed by wear-out of one or more components, resulting in a dramatic increase in the failure rate. Another possible second scenario not shown is where the steady-state failure rate (at the bottom of the bathtub curve) rises slowly, steadily reducing the inverter population throughout the entire product life, but not reaching a wear-out condition within the first 20 years. This second failure scenario appears equally as likely to occur due to the positive results of the accelerated life testing. However, infant mortality occurs in the first 1-3 years of product life, and because the SUN2000-330KTL-H2 string inverter under review had limited field data related to 330KTL, to determine which scenario the inverters will experience.

DNV acknowledges the long-term efforts of Huawei to refine the inverter design process, and the testing for reliability. DNV recommends providing more supporting field data for the models under review, and/or extensive inverter accelerated test data demonstrating a long product life. Extensive accelerated test data would include a large group of inverters operated for an accelerated period of greater than 25 years. When available, additional supporting field data on the SUN2000 inverter series that reflect inverter reliability trends should be used to update the failure rate model. As of the date of this report, the number of inverters model SUN2000-330KTL-H2 installed appears to be adequate to significantly diminish the likelihood of premature failures due to varying site conditions.

9.2 String inverter repair

As explained in section 8.3, Huawei reports that the string inverters can be repaired in a service depot. The inverter useful life projection presented by DNV is also based on the assumption that in a string inverter, a single component failure results in an inverter replacement. DNV notes that if workshop repairs (provided by Huawei in some markets) are accounted then the useful life can be extended up to 25 years.

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► SUN2000-330KTL-H2 Smart String Inverter For MEA, Eurasian



Max.
Efficiency
≥ 99.0%



Smart
Connector-level
Detection
(SCLD)



Smart
Self-cleaning
Fan
(SSCF)



IP66
Protection



MBUS
Supported



Smart
String-level
Disconnection
(SSLD)

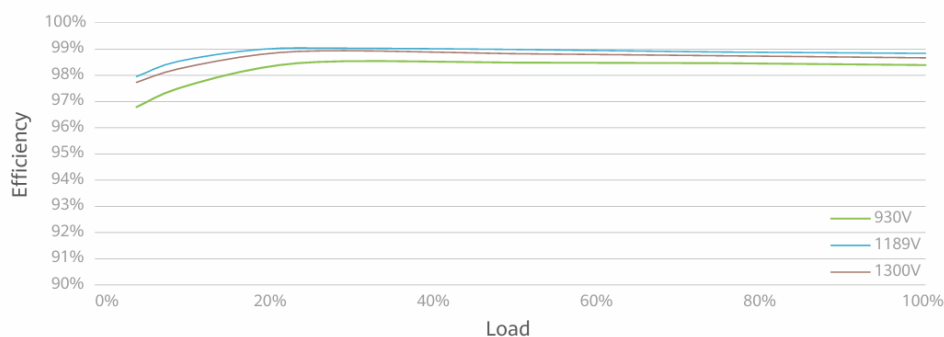


Smart IV Curve
Diagnosis
Supported

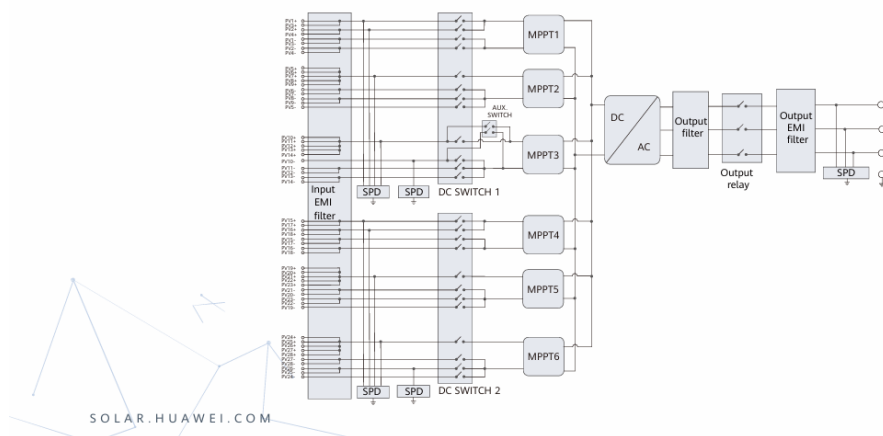


Surge
Arresters for
DC & AC

Efficiency Curve



Circuit Diagram



Technical Specifications

Efficiency	
Max. Efficiency	> 99.0%
European Efficiency	> 98.8%
Input	
Max. Input Voltage	1,500 V
Number of MPPT	6
Max. Current per MPPT	65 A
Max. Short Circuit Current per MPPT	115 A
Max. PV Inputs per MPPT	4/5/5/4/5/5
Start Voltage	550 V
MPPT Operating Voltage Range	500 V ~ 1,500 V
Nominal Input Voltage	1,080 V
Output	
Nominal AC Active Power	275,000 W ¹
Max. AC Apparent Power	330,000 VA
Max. AC Active Power (cosφ=1)	330,000 W
Nominal Output Voltage	800 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Nominal Output Current	198.5 A
Max. Output Current	238.2 A
Adjustable Power Factor Range	0.8 LG ... 0.8 LD
Total Harmonic Distortion	THD _i < 1% (Rated)
Protection	
Smart String-level Disconnection (SSLD)	Yes
Smart Connector-level Detection (SCLD)	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Detection	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
Residual Current Detection Unit	Yes
Communication	
Display	LED Indicators, USB + APP
USB	Yes
MBUS	Yes
RS485	Yes
General	
Dimensions (W x H x D)	1,048 x 753 x 395 mm
Weight (with mounting plate)	≤ 112 kg
Operating Temperature Range	-30°C ~ 60°C
Cooling Method	Smart Air Cooling
Max. Operating Altitude without Derating	4,000 m
Relative Humidity	0 ~ 100% (Non-condensing)
DC Connector	HH4SFD4TMS / HH4SMD4TMS
AC Connector	Support OT / DT Terminal (Max. 400 mm ²)
Protection Degree	IP 66
Anti-corrosion Protection	C5-Medium
Topology	Transformerless
Standards Compliance	
IEC 62109-1/-2, IEC 62920, IEC 60947-2, EN 50549-2, IEC 61683, etc.	



DNV

APPENDIX B IEC & EN CERTIFICATES

ATTESTATION

ATTESTATO

ATESTACIÓN

BESCHEINIGUNG

ATTESTATION



Product Service

Attestation of Conformity

No. N8A 041829 4883 Rev. 01

Model:	SUN2000-300KTL-H0	SUN2000-280KTL-H0	SUN2000-250KTL-H3
DC input terminal parameters:			
Max. DC voltage	1500 Vd.c.		
Isc	6*115 Ad.c.		
Operating DC voltage range	500-1500 Vd.c.		
Rated DC voltage	1080 Vd.c.		
Full-load voltage range	930-1300 Vd.c.		
Max. DC current	6*65 Ad.c.		
Over voltage category	II		
Grid output terminal parameters:			
Rated AC voltage	3W+PE, 800 Va.c.		
Rated AC frequency	50 Hz		
Rated output current	216.6 Aa.c.	202.1 Aa.c.	180.5 Aa.c.
Rated active/apparent power	300 kW/300 kVA	280 kW/280 kVA	250 kW/250 kVA
Max. continuous output current	238.2A	222.3A	198.5A
Max. active/apparent power	330 kW/330 kVA	308 kW/308 kVA	275 kW/275 kVA
Power factor range	0.8 leading – 0.8 lagging		
Over voltage category	III		
General			
Operating temperature range	-30°C ~ +60°C		
Protection class	I		
Enclosure	IP66		
Dimensions (W × H × D)	1048 mm × 732mm × 395 mm		

**Tested
according to:**

EN 62109-1:2010
EN 62109-2:2011

Page 3 of 3

This Attestation does not replace the regulatory EU Declaration of Conformity (DoC) and does not allow for CE marking. After preparation of the necessary documentation and establishing compliance to requirements of all applicable directives, the manufacturer may sign a DoC and apply the CE marking. The DoC is issued under the sole responsibility of the manufacturer.

TÜV SÜD Product Service GmbH • Ridlerstraße 65 • 80339 Munich • Germany



APPENDIX: Test Verification of Conformity

This is an Appendix to Test Verification of Conformity Number: 221115008SZN-VOC001.

Relevant Standards:

IEC 62920:2017
IEC 62920:2017/AMD1:2021
Photovoltaic power generating systems - EMC requirements and test methods for power conversion equipment

CISPR 11:2015+A1:2016
CISPR 11:2015+A1:2016+A2:2019
Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement

IEC 61000-6-4:2018*
Electromagnetic compatibility (EMC) – Part 6-4: Generic standards - Emission standard for industrial environments

IEC 61000-6-2:2016
Electromagnetic compatibility (EMC) – Part 6-2: Generic standards - Immunity for industrial environments

IEC 61000-3-11:2017
Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection

IEC 61000-3-12:2011
IEC 61000-3-12:2011/AMD1:2021
Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase

Note : * The standard IEC 61000-6-4 applies only to the Telecommunication/network port.

Peter Kang

Signature

Name: Peter Kang
Position: Senior Technical Supervisor
Date: 30 November 2022

This Verification is for the exclusive use of Intertek's client and is provided pursuant to the agreement between Intertek and its Client. Intertek's responsibility and liability are limited to the terms and conditions of the agreement. Intertek assumes no liability to any party, other than to the Client, in accordance with the agreement, for any loss, expense or damage occasioned by the use of this Verification. Only the Client is authorized to permit copying or distribution of this Verification. Any use of the Intertek name or one of its marks for the sale or advertisement of the tested material, product or service must first be approved in writing by Intertek. The observations and test/inspection results referenced in this Verification are relevant only to the sample tested/inspected. This Verification by itself does not imply that the material, product, or service is or has ever been under an Intertek certification program.

Intertek

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GFT-OP-11a (22-August-2019)



DNV



EU Declaration of Conformity

(No. CE-10218627)

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

declare that the product

Name/Trademark Smart PV Controller/HUAWEI
Model SUN2000-250KTL-H3,SUN2000-250KTL-H1,SUN2000-330KTL-H1
SUN2000-330KTL-H2,SUN2000-280KTL-H0,SUN2000-300KTL-H0

complies with the following directives:

- **2014/35/EU (Low Voltage Directive)**
- **2014/30/EU (EMC Directive)**
- **2011/65/EU & (EU) 2015/863 (RoHS Directive)**

For the evaluation of the compliance with these Directives, the following standards have been applied:

Safety	EN 62109-1:2010 EN 62109-2:2011
EMC	EN 62920:2017 EN 62920:2017+ A11:2020 EN 62920:2017+ A1:2021 EN 55011:2016 EN 55011:2016+A1:2017 EN 55011:2016+A11:2020 EN 55011:2016+A2:2021 EN 61000-6-4:2007* EN 61000-6-4:2007+A1:2011* EN IEC 61000-6-4:2019* EN 61000-6-2:2005 EN 61000-6-2:2005/AC:2005 EN IEC 61000-6-2:2019 EN 61000-3-11:2000 EN IEC 61000-3-11:2019 EN 61000-3-12:2011 Note:*The standards IEC/EN 61000-6-4 applies only to the Telecommunication/network port.
RoHS	EN IEC 63000:2018

This declaration of conformity is issued under the sole responsibility of the manufacturer.

Responsible for making this declaration is the:

☒ Manufacturer ☐ Authorised representative established within the EU

Signed for and on behalf of: Huawei Technologies Co., Ltd.

Print name/Title : LingHongDong / Regulation Compliance Manager

Shenzhen, China 2023-01-14 Ling Hong Dong
(Place) (Date) (Signature)

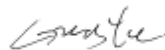
Certificate of Conformity

Certificate Number: CN-PV-220287

On the basis of the tests undertaken, the sample<s> of the below product have been found to comply with the requirements of the referenced specification<s>/standard<s> at the time the tests were carried out. It does not imply that Intertek has performed any surveillance or control of the manufacture(s). The manufacturer(s) shall ensure that the manufacturing process assures compliance of the production units with the examined products mentioned in this certificate.

Applicant:	Huawei Technologies Co., Ltd. Administration Building, Headquarters of Huawei Technologies Co., Ltd., Bantian, Longgang District, Shenzhen, Guangdong, 518129, China.
Product:	SOLAR INVERTER
Ratings & Principle Characteristics:	See appendix of Certificate of Conformity
Model:	SUN2000-330KTL-H1, SUN2000-330KTL-H2, SUN2000-250KTL-H1, SUN2000-275KTL-H1, SUN2000-250KTL-H3
Brand Name<s>:	 HUAWEI
Product Complies with:	IEC 61727:2004 Photovoltaic (PV) systems – Characteristics of the utility interface IEC 62116:2014 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters
Certificate Issuing Office Name & Address:	Intertek Testing Services Ltd. Shanghai West Area, 2nd Floor, No. 707, Zhangyang Road China (Shanghai) Pilot Free Trade Zone, Shanghai, P. R. China Accredited by ACCREDIA in accordance with ISO/IEC 17065:2012
Test Report No.<s>:	221019063GZU-002, 221019063GZU-003

Additional information in Appendix.



Signature

Certification Manager: Grady Ye
Date: 15 December 2022



PRD N° 306B

This Certificate is for the exclusive use of Intertek's client and is provided pursuant to the agreement between Intertek and its Client. Intertek's responsibility and liability are limited to the terms and conditions of the agreement. Intertek assumes no liability to any party, other than to the Client in accordance with the agreement, for any loss, expense or damage occasioned by the use of this Certificate. Only the Client is authorized to permit copying or distribution of this Certificate. Any use of the Intertek name or one of its marks for the sale or advertisement of the tested material, product or service must first be approved in writing by Intertek.

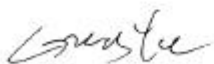
Certificate of Conformity

Certificate Number: CN-PV-230029

On the basis of the tests undertaken, the sample<s> of the below product have been found to comply with the requirements of the referenced specification<s>/standard<s> at the time the tests were carried out. It does not imply that Intertek has performed any surveillance or control of the manufacture(s). The manufacturer(s) shall ensure that the manufacturing process assures compliance of the production units with the examined products mentioned in this certificate.

Applicant:	Huawei Technologies Co., Ltd. Administration Building, Headquarters of Huawei Technologies Co., Ltd., Bantian, Longgang District, Shenzhen, Guangdong, 518129, China.
Product:	SOLAR INVERTER
Ratings & Principle Characteristics:	See appendix of Certificate of Conformity
Model:	SUN2000-330KTL-H1, SUN2000-330KTL-H2, SUN2000-250KTL-H1
Brand Name<s>:	 HUAWEI
Product Complies with:	EN 50530: 2010 + A1:2013 Overall efficiency of grid connected photovoltaic inverters
Certificate Issuing Office Name & Address:	Intertek Testing Services Ltd. Shanghai West Area, 2nd Floor, No. 707, Zhangyang Road China (Shanghai) Pilot Free Trade Zone, Shanghai, P. R. China Accredited by ACCREDIA in accordance with ISO/IEC 17065:2012
Test Report No.<s>:	221019063GZU-005

Additional information in Appendix.



Signature

Certification Manager: Grady Ye
Date: 13 January 2023



PRD N° 306B

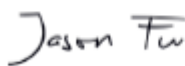
This Certificate is for the exclusive use of Intertek's client and is provided pursuant to the agreement between Intertek and its Client. Intertek's responsibility and liability are limited to the terms and conditions of the agreement. Intertek assumes no liability to any party, other than to the Client in accordance with the agreement, for any loss, expense or damage occasioned by the use of this Certificate. Only the Client is authorized to permit copying or distribution of this Certificate. Any use of the Intertek name or one of its marks for the sale or advertisement of the tested material, product or service must first be approved in writing by Intertek.

Test Verification of Conformity

Verification Number: 240315130GZU- VOC001

On the basis of the tests undertaken, the sample<s> of the below product have been found to comply with the requirements of the referenced specification<s>/standard<s> at the time the tests were carried out. This verification is part of the full test report<s> and should be read in conjunction with it <them>. This verification replaces previous verification number 240104118GZU- VOC001 dated: 11-Jan-2024.

Applicant Name & Address:	Huawei Technologies Co., Ltd. Administration Building, Headquarters of Huawei Technologies Co., Ltd., Bantian, Longgang District, Shenzhen, Guangdong, 518129, China.
Product Description:	SOLAR INVERTER
Ratings & Principle Characteristics:	See Appendix: Test Verification of Conformity
Models/Type References:	SUN2000-330KTL-H1, SUN2000-330KTL-H2, SUN2000-250KTL-H1
Brand Names:	 HUAWEI
Specification<s>/Standards:	IEC 61683:1999 Photovoltaic systems – Power conditioners – Procedure for measuring efficiency IEC 60068-2-1: 2007; IEC 60068-2-2: 2007; IEC 60068-2-14: 2009 IEC 60068-2-30: 2005; IEC 60068-2-6: 2007; IEC 60068-2-27: 2008 IEC 60068-2-64: 2008; IEC 60068-2-78: 2012; IEC 60068-2-11: 1981
Verification Issuing Office Name & Address:	Intertek Testing Services Shenzhen Ltd. Guangzhou Branch. Room101/301/401/102/202/302/402/502/602/702/802, No. 7-2, Caipin Road, Huangpu District, Guangzhou, Guangdong, China
Date of Tests:	13 Jun 2023 - 16 Jun 2023, 16 Mar 2024 - 31 Mar 2024 04 Jan 2024 - 10 Jan 2024
Test Report Number(s):	230526088GZU-001, Revision 1: 09 Apr 2024 240104118GZU-001, 10-Jan-2024
Additional information in Appendix.	



Signature

Name: Jason Fu
Position: Supervisor
Date: 09 Apr 2024

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UK Declaration of Conformity

(No. UK-10245565)

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

declare that the product

Name/Trademark SOLAR INVERTER/HUAWEI

Model SUN2000-330KTL-H2, SUN2000-330KTL-H1, SUN2000-300KTL-H0

complies with the following statutory instruments:

- **Electrical Equipment (Safety) Regulations 2016**
- **Electromagnetic Compatibility Regulations 2016**
- **The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012**

For the evaluation of the compliance with these statutory instruments, the following standards have been applied:

Safety	EN 62109-1:2010 EN 62109-2:2011
Electromagnetic Compatibility	EN 62920:2017 EN 62920:2017+A11:2020 EN 62920:2017+A1:2021 EN 55011:2016 EN 55011:2016+A1:2017 EN 55011:2016+A11:2020 EN 55011:2016+A2:2021 EN 61000-3-11:2000 EN IEC 61000-3-11:2019 EN 61000-3-12:2011 EN 61000-6-2:2005 EN 61000-6-2:2005/AC:2005 EN IEC 61000-6-2:2019 EN 61000-6-4:2007 EN 61000-6-4:2007/A1:2011 EN IEC 61000-6-4:2019
Restriction of the Use of Certain Hazardous Substances	EN IEC 63000:2018

This declaration of conformity is issued under the sole responsibility of the manufacturer.

Responsible for making this declaration is the:

☒ **Manufacturer** ☐ **Authorised representative established within the UK**

Signed for and on behalf of: Huawei Technologies Co., Ltd.

Print name/Title : LingHongDong / Regulation Compliance Manager

Shenzhen, China
(Place)

2023-02-21
(Date)

LingHongDong
(Signature)



中国认可
国际互认
检测
TESTING
CNAS L0310



Environment Test Report

Product Name: SUN2000HA

Product Model: SUN2000-300KTL-H0, SUN2000-280KTL-H0, SUN2000-330KTL-H1, SUN2000-330KTL-H2, SUN2000-250KTL-H1, SUN2000-250KTL-H3, SUN2000-275KTL-H1

Report Number: SYBH (H) 10137937

Reliability Laboratory of Huawei Technologies Co., Ltd.

No.2, New City Avenue, Songshan Lake Sci. & Tech. Industry Park, Dongguan, 523808, P.R.C
Tel: +86 769 23830808 Fax: +86 769 23837628

1 General Information

1.1 Standard Compliance

GB/T 2423.17:2008
IEC 60068-2-11:1981
ISO 9227-2017
ISO 12944-6-2018

Notes:

1. ISO 9227-2017 and ISO 12944-6-2018 have not been accredited by CNAS and A2LA

1.2 Test Location

Test Location1: Reliability Laboratory of Huawei Technologies Co., Ltd.
Address: No.2 New City Avenue Songshan Lake Sci. &Tech. Industry Park, Dongguan, Guangdong, P.R.C

1.3 Testing Environment Condition

Ambient Temperature: +22.2℃ to +26.6℃
Relative Humidity: 42.9% to 62.1%
Atmospheric Pressure: 100.9KPa to 101.1KPa

Project Status Notification

To: Ministry of Energy and Mines

We hereby inform you that the current status of the inverter IEC 62093:2022 certificate applied by Huawei Technologies Co., Ltd. is as follows:

Client: Huawei Technologies Co., Ltd
 Project No.: 64.290.24.30039.01
 Product: SOLAR INVERTER
 Model No.: SUN2000-300KTL-H0, SUN2000-280KTL-H0, SUN2000-250KTL-H3, SUN2000-250KTL-H1, SUN2000-275KTL-H1, SUN2000-330KTL-H1, SUN2000-330KTL-H2

Service applied: Test report
 Test standard: IEC 62093:2022
 Project Status: ☒ Testing in process as following:
 (as of the date this notification is issued) ☒ Full test - Initial test
☐ Full test - Re-test
☐ Construction check
☐ Other: (Update standard version)
☐ Testing completed – positive result:
☐ Preparing the technical report / project documentation
☐ Applying for the certificate
Remark: This status notification does NOT substitute a license or certification document, and does NOT authorize the use of any certification mark.
☐ Testing completed – negative result:
☐ Testing failed
☐ Documentation not complete
Remark: For details, please refer to the negative technical report, and/or contact the project engineer.
☐ Project on hold due to:
☐ Waiting for outstanding documentation from client
☐ Waiting for outstanding payments from client
☐ Other: (please specify)

Contact person at TÜV SÜD: For further questions about the above project, please contact:
 Stephen Yu
 Tel: +86 20 3815 3389
 Email: Stephen.yu@tuv-sud.com

Kind regards,

2024-07-17

Date

Stephen Yu
 Project Engineer



TÜV SÜD Certification and Testing
 (China) Co., Ltd. Guangzhou Branch
 TÜV SÜD Group

SF, Communication Building,
 163 Pingyun Rd, Huangpu West Ave.
 Guangzhou 510656
 P. R. China



**Guangdong Sushi Guangbo Testing
Technology Co., Ltd.**



中国认可
检测
TESTING
CNAS L12110

Test Report

No.: GDGT-H/R-202209-01-189-EN

Applicant: Huawei Digital Power Technologies Co., Ltd.

Applicant Address: No. 01, 39th Floor, R&D, Block A, Antoshan Headquarters Building, 33 Antoshan 6th Road, Xiang'an Community, Xiangmihu Street, Futian District, Shenzhen.

Laboratory: Guangdong Sushi Guangbo Testing Technology Co., Ltd.

Laboratory Address: Building No.4, Modern Enterprise Accelerator, No.24 Industrial East Road, Songshan Lake, Dongguan, P.R. China.

Date of test: Sep.28,2022~Sep.29,2022



Guangdong Sushi Guangbo Testing Technology Co., Ltd.
Modern Enterprise Accelerator, No.24 Industrial East Road, Songshan Lake, Dongguan, P.R. China.
Certificate Search: <http://www.stigd.com>

Tel: 0769-26268019

E-mail: gsrb@stigd.com

Page 1 of 11



Guangdong Sushi Guangbo Testing Technology Co., Ltd.

No.: GDGT-H/R-202209-01-189-EN

Test Report

i. Test sample

Product name: Inverter;

Product model: SUN2000-300KTL-H0,
SUN2000-280KTL-H0,
SUN2000-330KTL-H1,
SUN2000-330KTL-H2,
SUN2000-250KTL-H1,
SUN2000-275KTL-H1;

Product No.: 202209-01-189-1#;

Product quantity: 1 PCS;

Product size(mm): 1048*753*395;

Product weight(kg): 112;

Receipt of sample: Sent by the applicant;

Test sample arrived: Sep.28,2022;

Sample description: There is no visible damage of specimens judging through visual inspection before formal test at room temperature.

ii. Test results summary

Table 1 Test results summary

Test Items	Test Results	Conclusions	Address
Dustproof test -IP6X	Check after the test, there is no dust inside the sample, which meets the requirements of the qualified judgment standard and is judged to be qualified.	Pass	Building No.4
Waterproof test -IPX6	Check after the test, there is no water inflow inside the sample, which meets the requirements of the qualified judgment standard and is judged to be qualified.	Pass	Building No.4

Edited: Jiang Zhou Reviewed: Yongsheng Ye Approve: Baocan Li

Issue Date: Oct.14,2022

Guangdong Sushi Guangbo Testing Technology Co., Ltd.
Modern Enterprise Accelerator, No.24 Industrial East Road, Songshan Lake, Dongguan, P.R. China.
Certificate Search: <http://www.stigd.com>

Tel: 0769-26268019

E-mail: gsrb@stigd.com
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About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.