

Quality system revelation, the cruel birth process of inverter

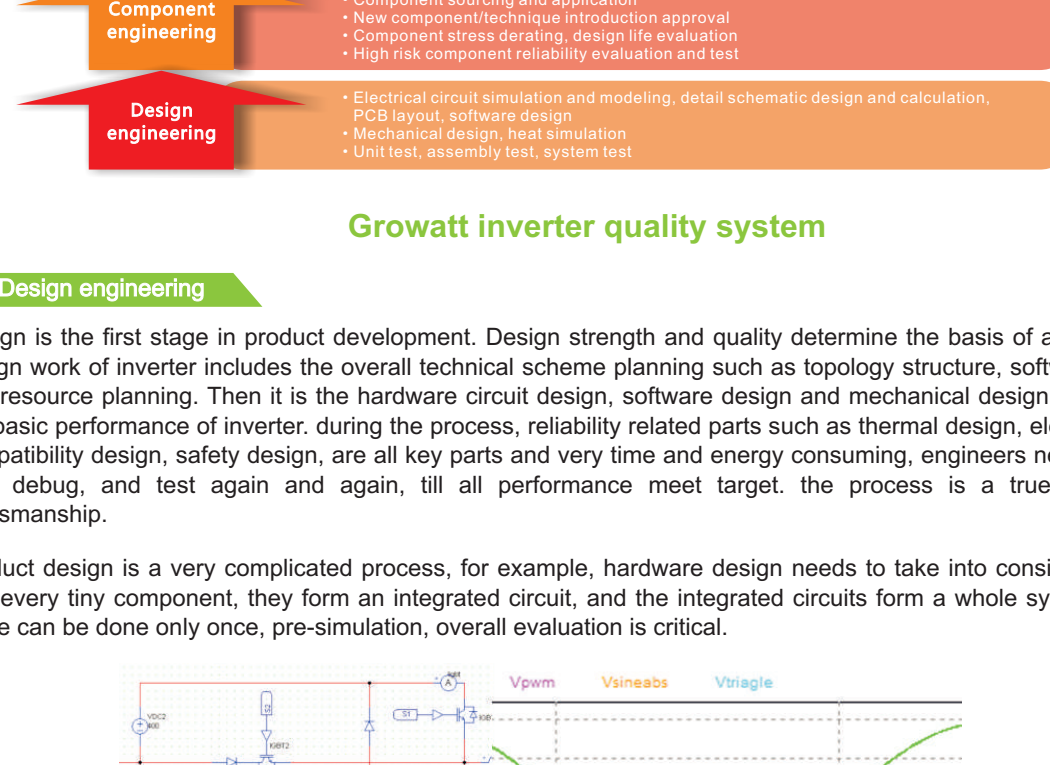
Introduction

Quality is the life of a company and customer, quality innovation is the driving force for company growth and social responsibility, product quality is the basis and basic guarantee for company development. With quality and innovation as the cornerstone, Growatt has been developing into a fast growing company.

The key factors to evaluate an inverter is key component selection, product feature, product function, innovation and reliability, each one is very important. but for inverter manufacturer the most important things are establishing a fully comprehensive and controllable product quality system. then the high adaptability to harsh environment and long life span of up to 20 years is ensured, along with the generation of a solar power plant.

From design to mass production each Growatt inverter model goes through 5 stages: Project kick off, functional prototype, engineering sample, pilot run and mass production. according to the technology that whole development cycle lasts 6-18 months.

During the whole development process, not only the initial functions and specs should be achieved, the R&D technical engineer, quality representative, marketing representative, customer service representative, tester representative ,manufacturing representative as a whole team, always bears in mind that 'product quality is company's lifeline', strictly follows 5 quality stages: design engineering ,component engineering, test engineering ,environment and reliability engineering ,manufacturing engineering. All 5 stages form an integrated system and works in a closed circle, aims at perfection in product.

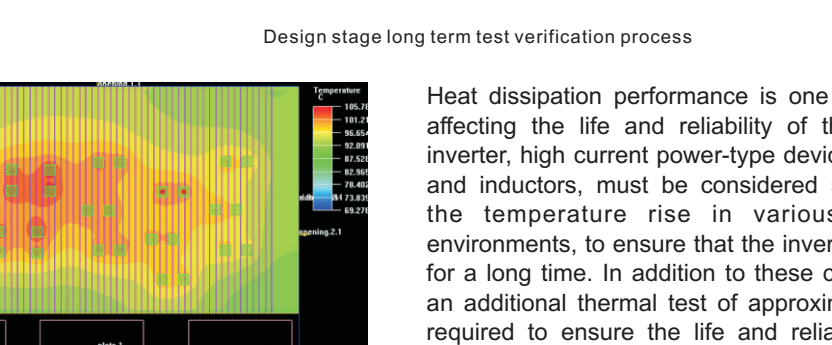


Growatt inverter quality system

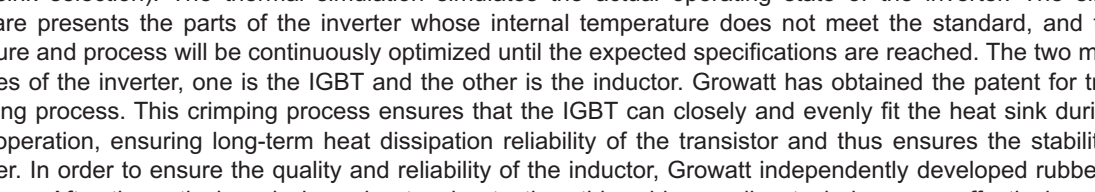
1. Design engineering

Design is the first stage in product development. Design strength and quality determine the basis of a product. The design work of inverter includes the overall technical scheme planning such as topology structure, software planning and resource planning. Then it is the hardware circuit design, software design and mechanical design, etc., to meet the basic performance of inverter. during the process, reliability related parts such as thermal design, electromagnetic compatibility design, safety design, are all key parts and very time and energy consuming, engineers need to design, test, debug, and test again and again, till all performance meet target. the process is a true reflection of craftsmanship.

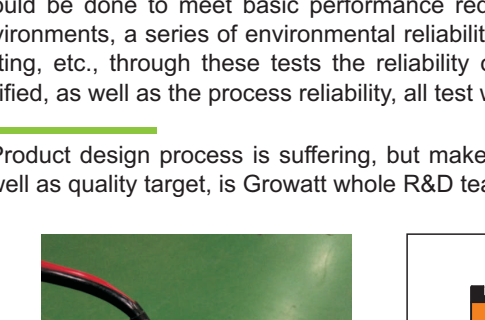
Product design is a very complicated process, for example, hardware design needs to take into consideration each and every tiny component, they form an integrated circuit, and the integrated circuits form a whole system, none of those can be done only once, pre-simulation, overall evaluation is critical.



After the simulation verification, the actual hardware circuit test platform will be built to perform long-term debugging for each integrated circuit and various functional circuits such as power supply circuit, boost circuit, inverter drive circuit, etc. along with software logic verification for over-voltage protection, over-current protection, ISO detection, and leakage protection; after the R&D project team has completed at least two rounds of self-test, a complete product test must be performed systematically by the DQ department independent of the R&D department. only after verification by DQ department can the product be released for pilot run.



Design stage long term test verification process

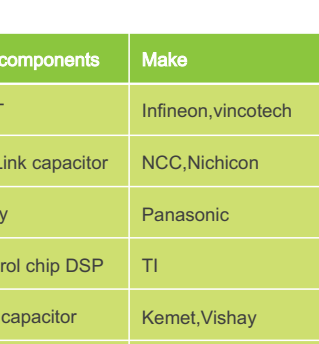


Inverter thermal simulation

Heat dissipation performance is one of the key factors affecting the life and reliability of the inverter. In the inverter, high current power-type devices, such as IGBTs and inductors, must be considered specially regarding the temperature rise in various harsh working environments, to ensure that the inverter can work stably for a long time. In addition to these critical components, an additional thermal test of approximately 30 points is required to ensure the life and reliability of the entire inverter.

After determining the inverter topology and circuit parameters, the thermal design work begins, which includes repeated modeling for thermal simulation and design optimization (structure layout optimization, process optimization, heat sink selection). The thermal simulation simulates the actual operating state of the inverter. The simulation software presents the parts of the inverter whose internal temperature does not meet the standard, and then the structure and process will be continuously optimized until the expected specifications are reached. The two main heat sources of the inverter, one is the IGBT and the other is the inductor. Growatt has obtained the patent for transistor crimping process. This crimping process ensures that the IGBT can be closely and evenly fit the heat sink during long-term operation, ensuring long-term heat dissipation reliability of the transistor and thus ensures the stability of the inverter. In order to ensure the quality and reliability of the inductor, Growatt independently developed rubber-sealed inductors. After theoretical analysis and extensive testing, this rubber-sealing technique can effectively accelerate heat transfer and control the temperature inside the inverter. After new inductor designed, basic parameter test should be done to meet basic performance requirements, and secondly to ensure its stability in extremely harsh environments, a series of environmental reliability tests will be done further, such as high and low temperature cycle testing, etc., through these tests the reliability of the materials such as the enclosure and sealing rubber can be verified, as well as the process reliability, all test will be done then on finished inverters.

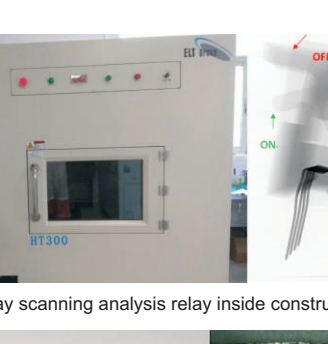
Product design process is suffering, but make all product design satisfy and even exceed user requirement as well as quality target, is Growatt whole R&D team's mission.



Patented rubber-sealed inductor (patent No.: 201520371560.8) Inductor patent technology



Transistor crimping technique compared with common pressure welding technique



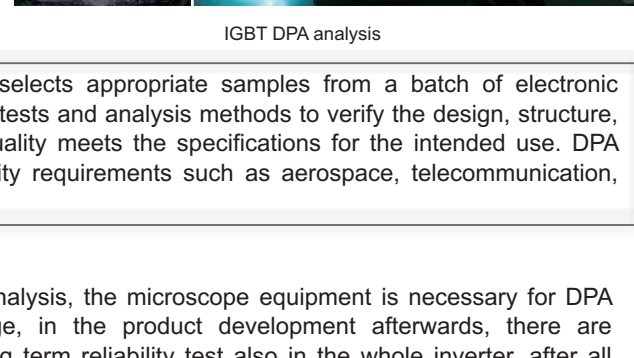
Regular pressure welding technique

2. Component engineering

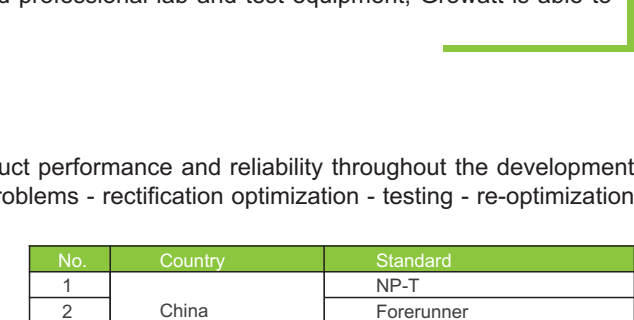
Growatt has a dedicated component reliability department, in which component quality is controlled by a number of device engineers with more than 10 years of experience. In the project kick off stage, when component selection and approval begins, all key components such as IGBT or IGBT module, capacitors, relays, sensors, etc., Growatt chooses the international 1st tier brand strictly to ensure product quality from inside out. At the same time, the component engineer will perform parameter verification on the component itself, there are up to 10 test items for a single PV terminal, such as flame retardancy test, insertion force test, DPA test, etc. for relays the tests include x-ray scanning, microscopic observation, DPA testing, etc.

Key components	Make	Country
IGBT	Infineon,vincolech	Germany
DC Link capacitor	NCC,Nichicon	Japan
Relay	Panasonic	Japan
Control chip DSP	TI	U.S.
Film capacitor	Kemet,Vishay	U.S.
Current transformer	LEM,VAC	U.S./ Germany

Growatt inverter key component use international tier 1 brand



X-ray scanning analysis relay inside construction



PV terminal anatomy analysis



IGBT DPA analysis

DPA is destructive physical analysis that randomly selects appropriate samples from a batch of electronic components and uses a series of destructive physical tests and analysis methods to verify the design, structure, materials, and whether the process manufacturing quality meets the specifications for the intended use. DPA analysis technology is generally used in high reliability requirements such as aerospace, telecommunication, medical equipment, and automotive electronics.

Growatt is one of the few companies that use DPA analysis, the microscope equipment is necessary for DPA analysis. Component approval is just the first stage, in the product development afterwards, there are performance tests and environment reliability test, long term reliability test also in the whole inverter, after all those tests a component sourcing process is finished. thus component sourcing is a huge and complicated project, with a professional team for quality control, and professional lab and testing equipment, Growatt is able to ensure the quality of inverter.

3. Test engineering

Test engineering is an important means of verifying product performance and reliability throughout the development process. Long-term testing of the product: discovery of problems - rectification optimization - testing - re-optimization until product performance is optimized.

During the design and development phase, the test engineer develops test cases based on the detailed specifications and application scenarios of the product. The test cases cover white box ultimate stress, input, output, comprehensive test, human-machine interface, environmental adaptability and long-term reliability, multi-dimensional, total more than 70 test items, from an independent and objective point of view, it provides fair technical judgment for the function and reliability of newly developed products to meet established specifications, and discovers product defects in advance to make design changes and ensure product quality. Growatt's R&D products are not only tested by the company's rigorous testing and verification department, but also need to pass more than 20 certification systems of various global standards and regulations, all done by accredited 3rd party labs.

No.	Country	Standard
1		NP-T
2	China	Forerunner
3		National grid LVRT
4		VDE-AR-N4105
5	Germany	VDE0126-1-1
6		BDEW
7	Australia	AS4777
8		CEC
9	India	IEC61683
10		IEC60068
11		MEA
12	U.S.	UL1741/1699B/Rule21
13	Thailand	CE10-21/0-16
14	Italy	IEC61727/62116
15	Hungary	EN50438
16	UK	GS9/G83
17	Europe	EN50383
18	CE	EN/IEC62109
19		EN/IEC61009
20	Belgium	C10/C11
21	Spain	RD1699

International standards for different countries

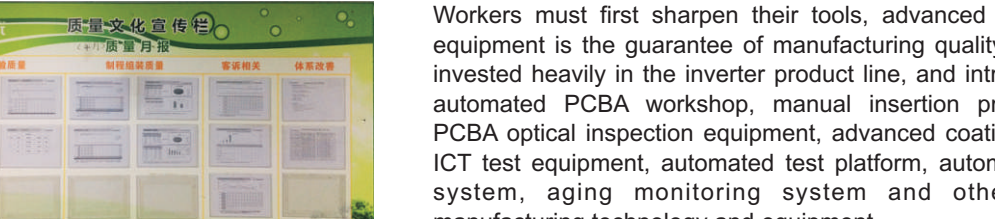
Part of the more than 70 test items for R&D prototypes

No.	Test item	No.	Test item
1	Input voltage range test	30	Grid-tied inrush current test
2	Input voltage and current surge test	31	Boost transistor voltage stress test
3	Input grounding impedance test	32	INV transistor voltage stress test
4	Reverse polarity test	33	SPS transistor voltage stress test
5	Cross test	34	BUS capacitor voltage and ripple test
6	High and low voltage cycle test	35	Boost hysterisis test
7	Over voltage test	36	HI-POt test
8	Input voltage and output power co-relation test	37	Night consumption test
9	Input to ground capacitor test	38	NTC test
10	Input over power test	39	AFCI test
11	Re-flux test	40	Voltage derating test
12	Standby consumption test	41	SVG function test
13	MPPT efficiency test	42	Output long term high 15voltage
14	Induced voltage test	43	Output inductor connection test
15	Output voltage range test	44	Grid failure/recovery test
16	Grid voltage fluctuation test	45	Input disconnect/re-connect test
17	Output frequency range test	46	Output motor connection test
18	Grid frequency fluctuation test	47	Grid fluctuation(sudden rise, sudden drop)
19	THDI,DCI,PF test	48	Low temperature storage
20	Output power and voltage co-relation test	49	Low temperature operation/start test
21	Output short circuit test	50	High temperature storage
22	Grid THD test	51	High temperature operation/start test
23	GFCl test	52	High humidity, high temperature storage
24	Grid failure/recovery test	53	High humidity, high temperature operation
25	Wrong connection test	54	Temperature cycle test
26	Output 1ms power cut test	55	Temperature-humidity cross test
27	Grid phase position variation test	56	
28	Grid THD injection test		
29	Frequency auto adjustment test		

Part of the more than 70 test items for R&D prototypes

4. Reliability engineering

To ensure stable and reliable operation of the inverter in a variety of environments, various reliability tests are required on the inverter. Growatt has a complete set of reliability test and verification equipment to conduct comprehensive reliability tests at all stages of R&D and mass production. for structural reliability, tests above IP65 protection level, such as waterproof test, air tightness test, drop test and vibration test for verification of mechanical strength, for environmental reliability, high and low temperature test, salt spray test, snow frost test, burn-in test, etc., to verify its adaptability in extreme harsh environments. In addition, HALT test and DFMEA failure mode analysis are required.

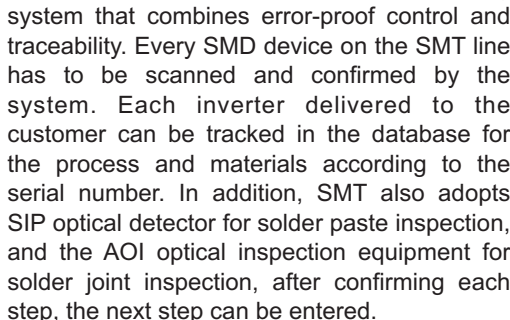


Simulation of inverter adaptability in harsh environment



HALT high speed aging test

HALT is a process for finding defects. It accelerates the exposure of test samples defects and weak points by setting progressively increasing environmental stresses. The exposed defects and faults will then be analyzed and corrected to improve reliability.



Long time reliability test 24 hours full load working more than 3years, same as normal working 15 years operation

5.Manufacture engineering

The manufacturing capability and technical level of the products are reflected in the design of production facilities and process flow. Growatt has a highly intelligent, standardized and automated production line, strict technical requirements, and strict quality control system runs through every link. Since its establishment, Growatt has put the core value of quality everywhere, and the quality has penetrated into the heart of every employee.



Quality culture bulletin board visible everywhere in the production workshop

Workers must first sharpen their tools, advanced manufacturing equipment is the guarantee of manufacturing quality, Growatt has invested heavily in the inverter production line, and introduced a fully automated PCBA workshop, manual insertion production line, PCBA optical inspection equipment, advanced coating line, ICT test equipment, automated test platform, automatic conveyor system, aging monitoring system and other advanced manufacturing technology and equipment.

PCBA workshop

PCBA refers to the circuit board inside the inverter, its manufacturing process determines the performance of the inverter. PCBA quality is an extremely important part of the whole manufacturing process of inverter. PCBA is divided into two major manufacturing processes by its component packaging, one is the SMT and the other is the manual insertion process.

A piece of PCB goes through solder paste - solder paste inspection - SMD mounting - anti-error material detection - reflow soldering - optical inspection finally forms a PCBA semi-finished product.

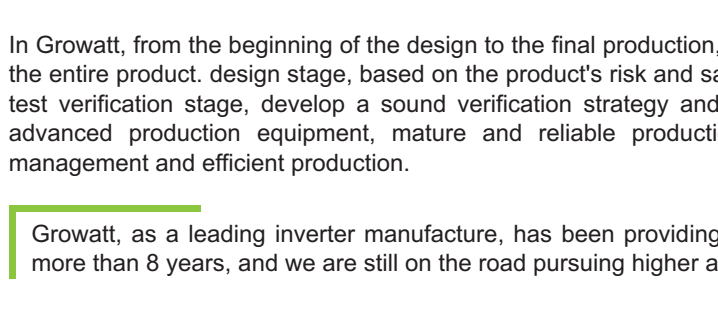


SMT automatic paste produce line

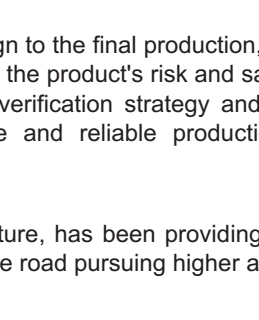


Error proof control equipment

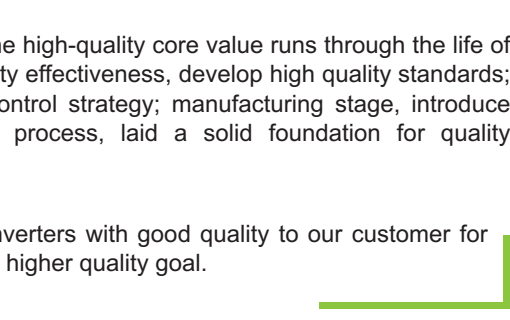
Growatt has established a full-process tracing system that combines error-proof control and traceability. Every SMD device on the SMT line has to be scanned and confirmed by the system. Each inverter delivered to the customer can be tracked in the database for the process and materials according to the serial number. In addition, SMT also adopts SIP optical detector for solder paste inspection, and the AOI optical inspection equipment for solder joint inspection, after confirming each step, the next step can be entered.



SPI solder paste inspection machine



AOI solder joint inspection machine



International tier 1 solder paste

In terms of accessories, Growatt also invest a huge amount. The solder paste is international top 1 brand Alpha. If the residue is high, it will cause PCBA CAF effect (metal electromigration), the stability will be greatly reduced.

After SMD soldering, the next step is the soldering of the manual insertion components, the semi-finished PCBA will pass manual insertion-wave soldering- lead cutting -AOI inspection-ICT inspection-manual inspection and welding, finally forming the finished PCBA, this process also requires multiple inspection processes to ensure the quality of the PCBA.



PCBA manual insertion workshop



AOI inspection instrument

In order to better protect the PCB and electronic devices, Growatt introduces a fully automatic coating workshop. The coating paint spray routes, coverage areas and paint thicknesses are strictly controlled by the process, and when spraying finished, it also needs to be confirmed by fluorescent lamps, and then finally dried by the drying line to ensure that the PCBA can withstand various harsh environments.

In Growatt, from the beginning of the design to the final production, the high-quality core value runs through the life of the entire product. design stage, based on the product's risk and safety effectiveness, develop high quality standards; test verification stage, develop a sound verification strategy and control strategy; manufacturing stage, introduce advanced production equipment, mature and reliable production process, laid a solid foundation for quality management and efficient production.

Growatt, as a leading inverter manufacture, has been providing inverters with good quality to our customer for more than 8 years, and we are still on the road pursuing higher and higher quality goal.