

Recommendation

ITU-T L.1241 (09/2023)

SERIES L: Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

Power feeding and energy storage

Methodologies for evaluating the functionality and performance of power supply units configured for servers



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Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

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Recommendation ITU-T L.1241

Methodologies for evaluating the functionality and performance of power supply units configured for servers

Summary

Recommendation ITU-T L.1241 provides comprehensive evaluation methods of power supply units configured for servers to evaluate electrical performances, functionalities and safety aspects.

History *

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Introduction

Recommendation ITU-T L.1241 describes comprehensive evaluation methods of power supply units (PSUs) for servers to evaluate electrical performances, functionalities and safety aspects. This Recommendation does not deal with the test for servers with PSUs nor the best practices to improve the various characteristics of PSUs, which can be defined in the future.

Henceforth, with the development of software-defined networking (SDN) and network functions virtualization (NFV) technology, traditional network structures will transition to SDN. Operators will use a large number of general-purpose servers to replace traditional specialized CT devices, which places higher requirements on the stability, security, performance, and other aspects of the servers. It is common for servers to operate without downtime 365 days a year, hence configuring reliable PSUs is crucial. In addition, due to the current environmentally friendly demand for energy conservation and greenhouse gas reduction, it is also necessary to consider the energy efficiency of equipment. But from the perspective of servers, this energy efficiency often refers to the computational power to the energy efficiency ratio. From the energy perspective, the main focus still lies on the energy efficiency of PSU.

The motivations for developing a comprehensive evaluation method regarding the functionality and performance of PSU for servers are as follows:

- Currently, the evaluation of PSU is mostly focused on energy efficiency, which is an important factor but is not comprehensive enough. There exist several server energy efficiency certification methods that are used in the industry. The certification methods classify the efficiency of servers into several levels based on the efficiency. However, as the server technology progresses, it is not difficult to achieve the highest level of certification that considers the energy efficiency only. Further, considering only the energy efficiency of PSU cannot provide a full understanding of the various characteristics of PSU, such as the power supply system that PSU can support, no-load power consumption, load distribution management methods, safety and protection of PSU, and so on. Therefore, it is necessary to establish a more comprehensive evaluation method to evaluate the various aspects of PSU including the electrical performances, functionalities, and safety.
- The server manufacturers usually do not develop and produce PSUs instead they adopt PSUs from PSU vendors. Thus, it is necessary to choose adequate PSUs based on the requirements and evaluation of PSUs. To check whether the PSU requirements for the servers are met or not, a comprehensive consideration is needed to fully understand the characteristics of PSU.
- From the user's point of view, when a user purchases a server, the configured PSU is integrated with the server. However, there exists no evaluation method for PSU characteristics, so it is difficult for users to determine the reliability and safety of the server and PSU. The difficulty can cause an unexpected problem for the safe operation of the server. If the evaluation methods for PSUs are developed, users can easily refer to the evaluation methods to test and evaluate the performance of the purchased PSUs.
- The development of the evaluation methods for PSU can also guide the technical progress of PSU manufacturers to meet the needs of the users. It can also guide server manufacturers to pay attention to PSU, avoiding the problem of server manufacturers' low motivation for supporting more energy-saving and efficient power supply methods.

Recommendation ITU-T L.1241

Methodologies for evaluating the functionality and performance of power supply units configured for servers

1 Scope

This Recommendation provides comprehensive evaluation methods of power supply units configured for servers to evaluate electrical performances, functionalities and safety aspects.

The functional features and performances evaluated mainly include input voltage range and rated frequency, total harmonic distortion (THD) of voltage and current, no-load power consumption, power factor, energy efficiency, load distribution management, telemetry, telecommunication, telecontrol, safety and protection.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T L.1200] Recommendation ITU-T L.1200 (2012), *Direct current power feeding interface up to 400 V at the input to telecommunication and ICT equipment.*
- [ITU-T L.1206] Recommendation ITU-T L.1206 (2017), *Impact on ICT equipment architecture of multiple AC, -48VDC or up to 400 VDC power inputs.*
- [ITU-T L.1310] Recommendation ITU-T L.1310 (2020), *Energy efficiency metrics and measurement methods for telecommunication equipment.*
- [ITU-T L.1315] Recommendation ITU-T L.1315 (2017), *Standardization terms and trends in energy efficiency.*
- [EN 50563] CENELEC EN 50563:2011, *External a.c. – d.c. and a.c. – a.c. power supplies – Determination of no-load power and average efficiency of active modes.*
- [ETSI EN 300 132-1] ETSI EN 300 132-1 v2.1.0 (2019), *Environmental Engineering (EE); Power supply interface at the input to Information and Communication Technology (ICT) equipment; Part 1: Alternating Current (AC).*
- [IEC 60038] IEC 60038:2009, *IEC standard voltages.*
- [IEC 60332-1-2] IEC 60332-1-2:2004/AMD1:2015, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame.*
- [IEC 60990] IEC 60990:2016, *Methods of measurement of touch current and protective conductor current.*
- [IEC 61000-2-2] IEC 61000-2-2:2002/AMD1:2017, *Amendment 1 – Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems.*

[IEC 61000-3-2]	IEC 61000-3-2:2018+AMD1:2020, <i>Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).</i>
[IEC 61000-4-7]	IEC 61000-4-7:2002/A1:2009, <i>Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto.</i>
[IEC 61180]	IEC 61180:2016, <i>High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment.</i>
[IEC 61558-1]	IEC 61558-1:2017, <i>Safety of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests.</i>
[IEC 62301]	IEC 62301:2011, <i>Household electrical appliances – Measurement of standby power.</i>
[IEC 62368-1]	IEC 62368-1:2023, <i>Audio/video, information and communication technology equipment – Part 1: Safety requirements.</i>

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 energy efficiency (EE) [b-ITU-T L.1350]: The relation between the useful output and energy consumption.

3.1.2 power [b-ITU-T L.1330]: The rate at which energy is transmitted. Power is measured in units of watts.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 power supply unit for server: A power conversion unit embedded in the server equipment to convert alternating current (AC) or up to 400 volts direct current (VDC) input voltage into low voltage.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
DC	Direct Current
EE	Energy Efficiency
PSU	Power Supply Unit
THD	Total Harmonic Distortion
VDC	Volts Direct Current

5 Conventions

None.

6 Methodology for evaluating performance of a power supply unit

This clause includes evaluation methods of performance indicators such as input voltage range, input rated frequency and frequency fluctuation range, total harmonic distortion (THD), power factor, no-load power consumption, and energy efficiency.

The test schematic can be seen in Figure 1. Since the output of the power supply unit (PSU) is direct current (DC) voltage, according to the reactance formula $Z = R + jX$, the impact of capacitive or inductive loads on the performance evaluation of the PSU can be ignored. Therefore, using resistive loads in the evaluation method without considering inductive or capacitive loads can effectively evaluate the performance of PSUs.

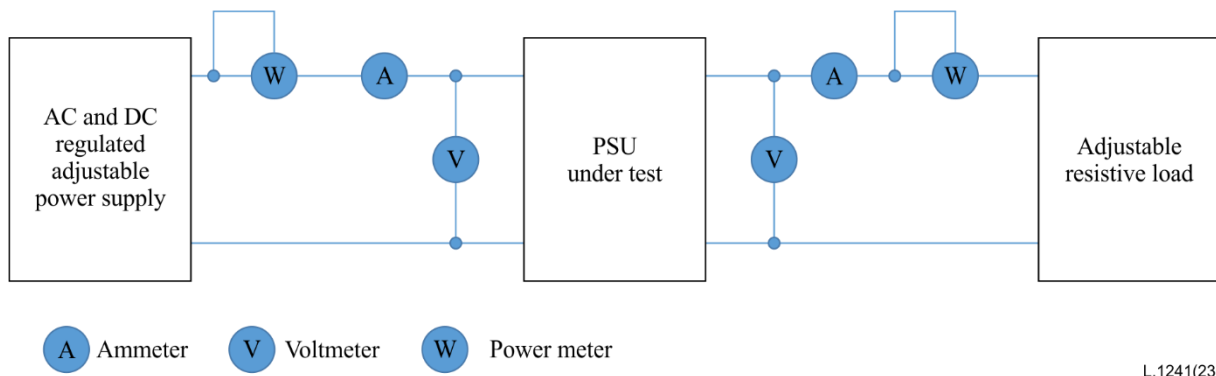


Figure 1 – Test schematic of PSU

6.1 General measurement conditions

6.1.1 Environmental conditions

As specified in [ITU-T L.1310], the PSU should be evaluated at an ambient temperature of 25 ± 3 °C, relative humidity of 30% to 75%, and a site pressure between 860 to 1 060 hPa.

6.1.2 Electrical conditions

According to [ITU-T L.1315], the assessment methods of performance indicators for PSU with DC input voltage shall be evaluated at $\pm 4\%$ of the specified float voltage. PSU with alternating current (AC) input voltage shall be evaluated at $\pm 5\%$ of the specified voltage and $\pm 1\%$ of the specified frequency.

The assessment methods of clauses 6.2 and 6.3 are not applicable to clause 6.1.2 completely.

6.2 Input voltage range

The PSU currently on the market can be supplied by an AC power, up to 400 VDC power, or hybrid power supply modes. The input voltage range of the PSU reflects the adaptability of the PSU to the fluctuation tolerance of the input voltage.

The nominal voltage for an AC grid source of 230 V single phase and 400 V three phase is defined according to [IEC 60038]. In addition, a wide worldwide nominal single phase AC voltage range from 100 V to 240 V is commonly used, along with a corresponding nominal 3 phase voltage range from 173 V to 415 V.

The AC input voltage of the PSU shall comply with the specified nominal voltage above. According to [IEC 60038], the supply voltage should not differ from the nominal voltage of the system by more than $\pm 10\%$, and the voltage drop recommended should not be greater than 4%. When taking voltage drops into account, [ETSI EN 300 132-1] gives the calculation method of the input voltage range. For PSU with up to 400 VDC input voltage, the minimum and maximum voltages refer to [ITU-T L.1200].

NOTE 1 – Product manufacturers can use a wide voltage range as the input voltage range of the PSU in order to apply for different nominal voltage systems in different regions.

NOTE 2 – According to the capabilities of product manufacturers, the allowable input voltage range of the PSU in practice may slightly exceed the specified voltage range within a certain limit.

To evaluate whether the PSU can work normally within a certain input voltage range, the test methods shall refer to [ETSI EN 300 132-1] for AC input and [ITU-T L.1200] for DC input.

6.3 Input rated frequency and frequency fluctuation range

The input rated frequency of PSU with AC input voltage is specified according to the frequency adopted by each country and region, and the rated frequency adopted by most countries and regions is 50 Hz or 60 Hz. At present, the input frequency fluctuation range of PSU produced by manufacturers usually ranges from 47 Hz to 63 Hz, so that the PSU can be used in these areas. For this reason, the range of $\pm 5\%$ of the rated frequency is recommended.

The evaluation method is to verify whether the PSU with AC input voltage can work normally when the input frequency is at the rated frequency as well as within the input frequency fluctuation range.

The test procedure should be as follows:

Step 1 – Connect the circuit according to Figure 1 and start PSU. Adjust the AC input voltage and frequency to meet the requirements in clause 6.1.2. The PSU shall work normally.

Step 2 – Adjust the input frequency to a lower-frequency limit, and the DC output with full load current. The PSU shall work normally.

Step 3 – Adjust the input frequency to the upper-frequency limit, and the DC output with full load current. The PSU shall work normally.

6.4 Total harmonic distortion (THD) of voltage and current

Total harmonic distortion (THD) of voltage and current produced by PSU can be injected into the public supply system. In order to reduce the impact of THD on the public supply system, it is necessary to limit them.

The compatibility level for the total harmonic distortion of voltage is 8% specified in [IEC 61000-2-2]. The limits of total harmonic distortion of current for PSU can be referred to [IEC 61000-3-2]. Testing and measurement techniques can be referred to [IEC 61000-4-7].

It should be noted that the THD of PSU may be better than the compatibility level according to different regions' regulations.

6.5 No-load power consumption

No-load power consumption is used to evaluate the input active power consumption of the PSU in hot standby mode, where PSU can provide immediate operation upon demand. In general, no-load power consumption is positively correlated with the rated power of the PSU.

Based on the main product series of PSUs in the market, most mainstream manufacturers can achieve no-load power consumption of PSUs within 1% of rated power, some examples of test results are in Appendix II. The no-load consumption can reach even stricter targets in practice as technical solutions appearing on the market show this to be feasible, but the cost will definitely be higher.

The test of no-load power consumption shall be made in accordance with [IEC 62301] but with the AC and DC cables provided with the product [EN 50563].

6.6 Power factor

The power factor refers to the ratio of the active power to the apparent power of the AC circuit. Power factor is an important technical indicator for PSU with AC input, as it reflects the efficiency of the

PSU in utilizing the electrical energy provided by the power supply. Considering its environmental impact, it would be better if this indicator were as high as possible at a certain load rate.

In order to evaluate this indicator, some documents in different regions (see Appendix I) provide the specified values of the power factor for PSU with different load rates (e.g., 20%, 50%, 100% of rated load), so as to represent the power factor performance of PSU under low load, half load, and full load operating conditions.

The test procedure should be as follows:

Step 1 – Connect the circuit according to Figure 1 and start PSU. Adjust the AC input voltage and frequency to meet the requirements in clause 6.1.2. The PSU shall work normally.

Step 2 – Adjust the load current to different load rates respectively and read the input power factor on the power quality analyser.

6.7 Energy efficiency

Energy efficiency (EE) is an important indicator for evaluating the performance of PSU, which can reflect the energy utilization efficiency of PSU under normal operating conditions. The goal of all users and manufacturers is to maximize the energy efficiency (EE) of PSU at different load rates. Considering the balance between technical capabilities and costs, this indicator is often graded in relevant documents or standards in different regions for users and manufacturers to make reasonable choices. However, in the current context of low-carbon and sustainable development, the requirements of energy efficiency (EE) for PSU will become increasingly strict. (Appendix I provides requirements on power factor and energy efficiency in some documents.)

In order to evaluate this indicator, it is necessary to adjust the output of the PSU at different load rates respectively, e.g., 10%, 25%, 50%, 75%, and 100%. The test methods shall be made in accordance with the [ITU-T L.1310].

The test procedure should be as follows:

Step 1 – Connect the circuit according to Figure 1 and start PSU. Adjust the AC input voltage and frequency to meet the requirements in clause 6.1.2. The PSU shall work normally.

Step 2 – Adjust the load current to different load rates respectively and record the efficiency on the power quality analyser.

6.8 PSU level classification

PSU can be classified on different levels (e.g., Level 1, Level 2, Level 3...) depending on their characteristic. According to customer needs, manufacturers need to declare at which level their PSU can be classified.

The basis for PSU level classification may not be a unified classification standard, as different certification requirements vary in different regions, and customers can also customize according to their own needs due to the cost and performance considerations.

Normally, PSU levels can be classified according to its energy efficiency (see 80 PLUS in Appendix I). No-load power consumption can also be used as the classification basis for PSU, but this indicator is often related to the rated power of PSU, for PSU with higher rated power may have more complex internal circuits. Therefore, when level classification is based on this indicator, it is necessary to consider the rated power of PSUs.

7 Methodology for evaluating the functionality of PSU

This clause includes evaluation methods of functionality features such as load distribution management, telemetry, telecommunication, telecontrol, and automatic power recovery functions.

The test schematic is seen in Figure 2.

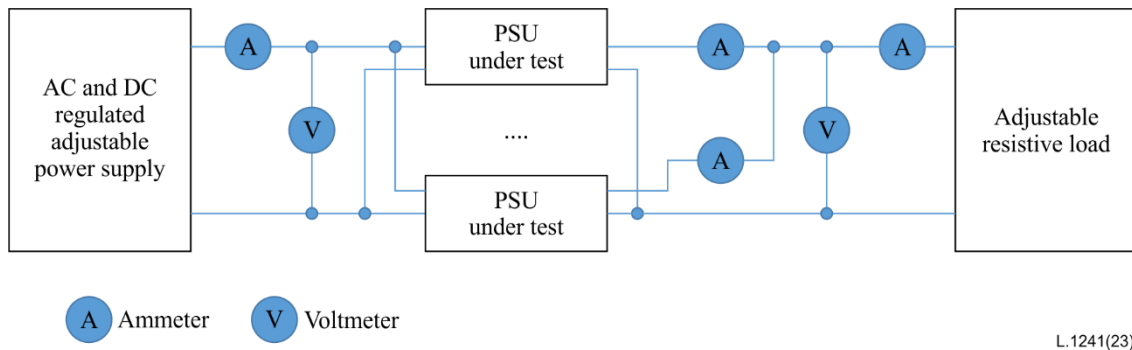


Figure 2 – Test schematic of PSU

7.1 Load distribution management

A server may be configured with two or more PSUs. These PSUs may have architectures of N , $2N$ or $N+M$ ($M < N$) in practical use for a server.

- PSUs with architectures of N can be seen in Figure 3. The total number of PSUs is N , which can provide power to the server with one single power source input.
- PSUs with architectures of $2N$ can be seen in Figure 4. The total number of PSUs is $2N$, which are evenly divided into 2 sets with different power source inputs for each set.
- PSUs with architectures of $N+M$ ($M < N$) can be seen in Figure 5. The total number of PSUs is $N+M$, which are divided into 2 sets with one set being N and the other set being M . These two sets have different power source inputs.

It is necessary to consider the load distribution management function of PSUs to achieve a better work performance. During the operation of multiple PSUs, there are several control mechanisms such as load distribution and even an imbalanced operation with a single PSU. It should carefully select how to control the operation of multiple PSUs based on the characteristics of power sources and server loads. When power conversion efficiency drops due to a light load operation with load distribution control, there is a case of operation with a load rate of better efficiency by controlling the number of PSUs. On the other hand, rather than load balancing of multiple PSUs, there is a case of imbalanced operation with a single PSU, which may bring better energy efficiency.

The load distribution management function is controlled by the system monitoring unit. In load distribution management, it is necessary to consider the load sharing performance of the working PSUs, because it will affect the overall output stability and service life of the system. The imbalance of output current sharing can be used to evaluate the load sharing performance of the PSU.

7.1.1 Load sharing mode

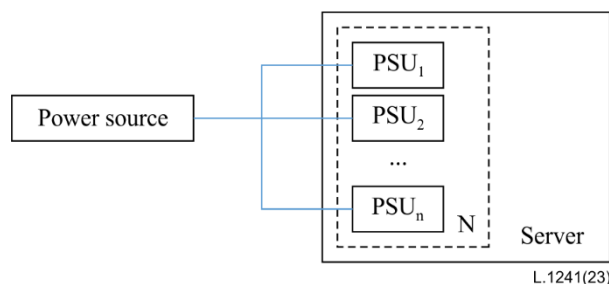


Figure 3 – PSUs with the architecture of N

When there are multiple PSUs working with the architecture of N in the condition of one single power source input (e.g., either AC or up to 400 VDC input from one power source), it is necessary to consider the load sharing performance of these PSUs, which can be evaluated by testing the imbalance of output current sharing. When one PSU fails, the others will automatically bear all the loads and redistribute the load, so that the output voltage and current shall keep working continuously. The load sharing of each PSU output is recommended not to be imbalanced.

NOTE – With a light load, the load sharing of each PSU output may be imbalanced.

The test method for the imbalance of output current sharing should be as follows:

Step 1 – Connect the circuit according to Figure 2.

Step 2 – Adjust the input voltage of the tested PSUs to the rated value. Turn on all the tested PSUs one by one and adjust the DC output voltage to the normal working value.

Step 3 – Set the working mode to load sharing mode. Adjust the load current to 50% and 100% of the rated load value respectively and record the current value of each tested PSU.

Step 4 – According to the test records, calculate the imbalance of output current sharing of each tested PSU under different output voltage and current. The calculation formula is as follows.

$$\delta_1 = (K_1 - K) \times 100\%$$

$$\delta_2 = (K_2 - K) \times 100\%$$

$$\delta_n = (K_n - K) \times 100\%$$

$$K_1 = I_1 / I_H$$

$$K_2 = I_2 / I_H$$

$$K_n = I_n / I_H$$

$$K = \Sigma I / nI_H$$

Where,

I_1, I_2, \dots, I_n – output current value borne by each tested PSU

I_H – rated output current of the tested PSU

ΣI – total output current of all the tested PSUs.

7.1.2 Optimal efficiency automatic adjustment working mode

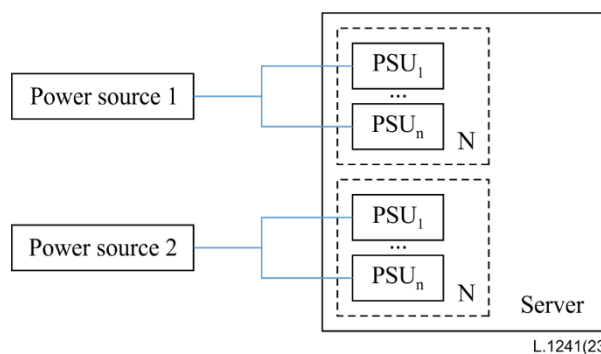


Figure 4 – PSUs with the architecture of 2N

In the condition of two different power source inputs (e.g., both AC or up to 400 VDC input from two different power sources, or one set with AC input and the other set with up to 400 VDC input), PSUs with the architecture of 2N (one set is N) can adopt optimal efficiency automatic adjustment

mode. This mode relies on the communication between PSUs and system monitoring and adjusts the load distribution proportion borne by the two sets of PSUs through negative feedback circuits to achieve optimal work efficiency. The load sharing of each PSU output in one set is recommended not to be imbalanced.

7.1.3 Active and standby working mode

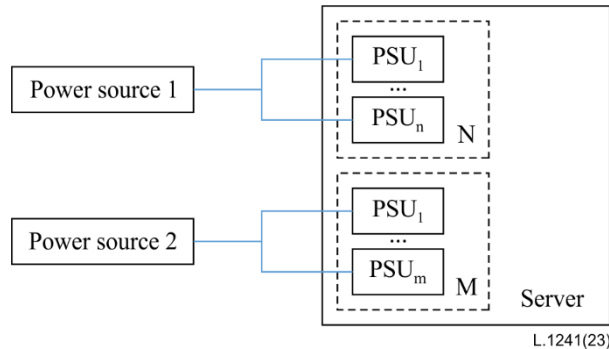


Figure 5 – PSUs with the architecture of N+M

In the condition of two different power source inputs (e.g., one set with AC input and another set with up to 400 VDC input), PSUs with the architecture of $2N$ (one set is N) or $N+M$ (one set is N , another set is M , $M < N$), can adopt active and standby mode. In this mode, two sets of PSUs can accept the system monitoring command to make one set to bear all the load, which is called active mode, and the other set automatically in the hot standby state with no load. Hot standby state refers to [ITU- T L.1206].

When the load rate of the active set exceeds some specific value, the active and standby working mode is automatically released and may return to the load sharing mode. In the active and standby mode, the load sharing of each PSU output within the active set is recommended not to be imbalanced.

7.2 Monitoring and control

Monitoring and control are very important functions in controlling and knowing the status of PSU. Monitoring and control refers to the exchange of information between PSU and the information communication equipment. The information that shall be available is as follows:

- Measured of analogue signal: output voltage and current of the PSU are recommended to be remotely available.
- Alarm/status: Power on/off, high temperature, current limited/unlimited, failure/normal, load distribution management.
- Control/settings: Power on/off, optimal efficiency automatic adjustment working mode, active and standby working mode.

Test conditions refer to clause 6.1.

7.3 Automatic power recovery function

After the input power is cut off and restored, the PSU shall be able to automatically return to normal operation in case the PSU has an automatic recovery function.

8 Methodology for evaluating safety and protection of PSU

This clause includes evaluation methods of safety and protection of the PSU.

8.1 Insulation resistance and dielectric strength

For the requirement and measurements of insulation resistance refer to [IEC 61558-1]. The insulation resistance is measured with a DC voltage of approximately 500 V applied, the measurement being made 1 minute after application of the voltage. Insulation resistance between hazardous live parts and the body, input circuits, and output circuits for basic insulation should not be less than 2 M Ω .

The dielectric strength test can only be carried out after the PSU passes the insulation resistance test. Immediately after the test of insulation resistance, the insulation is subjected for 1 minute to a dielectric strength voltage of substantially sinusoidal-wave form at 50/60 Hz. The value of the dielectric strength test voltage and the points of application refer to [IEC 61558-1]. Details of the test method to be used are given in [IEC 61180].

8.2 Touch current

The requirement and measurements of the touch current of PSU refers to [IEC 61558-1] and [IEC 60990].

8.3 Resistance of the protective bonding system

The protective bonding system in the PSU consists of a single conductor or a combination of conductive parts, connecting a main protective earthing terminal to a part of the equipment that is to be earthed for safety purposes. Protective bonding conductors and their terminations shall not have excessive resistance.

The measurement is made between the main protective earthing terminal and each measuring point in the PSU that is required to be earthed. Test method and compliance criteria can be seen in [IEC 62368-1].

8.4 Flame retardancy of materials

As specified in [IEC 62368-1], the flame retardant grade of the printed circuit board used for PSU shall meet the V-0 grade. The flame retardant grade of the plastic insulation layer of the conductor shall meet the requirements in [IEC 60332-1-2], and other plastic materials shall meet the V-1 grade specified in [IEC 62368-1].

Appendix I

Power factor and energy efficiency in some documents

(This appendix does not form an integral part of this Recommendation.)

I.1 80 PLUS specification of US Department of Energy

80 PLUS specification is a performance specification and certification programme for internal power supply units (PSUs), which is recognized by ENERGY STAR® and the European Union (EU) and well known among PSU manufacturers. It provides six levels of certification from standard to titanium for internal power supplies at increasing levels of energy efficiency.

There are currently five categories for certifications including 115V internal desktop, 230V EU internal desktop, 115V industrial, 230V internal AC and 380V internal DC data centre power supplies. The performance specification requires power supplies in computers and servers to be 80% energy efficient or greater at 20%, 50% and 100% of rated load with a true power factor of 0.9 or higher.

The following table gives energy efficiency and power factor in 80 PLUS certification.

Table I.1 – Energy efficiency and power factor in 80 PLUS certification

80 PLUS certification	% of rated load	80 PLUS	Bronze	Silver	Gold	Platinum	Titanium
115V internal non-redundant	10%	-	-	-	-	-	90%
	20%	80%	82%	85%	87%	90%	92%, PFC ≥ 0.95
	50%	80%	85%, PFC ≥ 0.90	88%, PFC ≥ 0.90	90%, PFC ≥ 0.90	92%, PFC ≥ 0.95	94%
	100%	80%, PFC ≥ 0.90	82%	85%	87%	89%	90%
115V industrial	10%	-	-	80%	82%	85%	-
	25%			85%, PFC ≥ 0.90	87%, PFC ≥ 0.90	90%, PFC ≥ 0.95	
	50%			88%	90%	92%	
	100%			85%	87%	90%	
230V EU internal non-redundant	10%	-	-	-	-	-	90%
	20%	82%	85%	87%	90%	92%	94%, PFC ≥ 0.95
	50%	85%, PFC ≥ 0.90	88%, PFC ≥ 0.90	90%, PFC ≥ 0.90	92%, PFC ≥ 0.90	94%, PFC ≥ 0.95	96%
	100%	82%	85%	87%	89%	90%	91%
230V internal redundant	10%	-	-	-	-	-	90%
	20%		81%	85%	88%	90%	94%, PFC ≥ 0.95
	50%		85%, PFC ≥ 0.90	89%, PFC ≥ 0.90	92%, PFC ≥ 0.90	94%, PFC ≥ 0.95	96%
	100%		81%	85%	88%	91%	91%
	10%	-	80%	82%	85%	88%	90%

Table I.1 – Energy efficiency and power factor in 80 PLUS certification

80 PLUS certification	% of rated load	80 PLUS	Bronze	Silver	Gold	Platinum	Titanium
380V DC internal redundant	20%		82%	85%	88%	90%	94%
	50%		85%	89%	92%	94%	96%
	100%		82%	85%	88%	91%	91%

I.2 Ecodesign requirements of the European Union

Ecodesign is a new rule set by the European Union that aims to gradually improve the energy efficiency of products. The standard covers all energy consuming products in the household, commercial and industrial sectors. The purpose of ecodesign is to achieve the overall goal of low carbon, efficient, and sustainable development of the European Union by eliminating the worst performing products in the market.

From 1 March 2020, for servers and online data storage products, with the exception of direct current servers and direct current data storage products, the PSU efficiency at 10%, 20%, 50% and 100% of the rated load level and the power factor at 50% of the rated load level shall not be less than the values reported in the following table.

Table I.2 – Minimum PSU efficiency and power factor requirements from 1 March 2020

	Minimum PSU efficiency				Minimum power factor
% of rated load	10%	20%	50%	100%	50%
Multi output	-	88%	92%	88%	0.90
Single output	-	90%	94%	91%	0.95

From 1 January 2023, for servers and online data storage products, with the exception of direct current servers and direct current data storage products, the PSU efficiency at 10%, 20%, 50% and 100% of the rated load level and the power factor at 50% of the rated load level shall not be less than the values reported in the following table.

Table I.3 – Minimum PSU efficiency and power factor requirements from 1 March 2023

	Minimum PSU efficiency				Minimum power factor
% of rated load	10%	20%	50%	100%	50%
Multi output	-	90%	94%	91%	0.95
Single output	90%	94%	96%	91%	0.95

I.3 Procurement requirements of the People's Republic of (China)

In order to promote the green and low-carbon development of the digital industry and accelerate the green transformation of data centres, departments of China jointly formulated and released the "Green data centre government procurement demand standards (trial)" document in March 2023, which was implemented from 1 June, 2023.

The following table gives the energy efficiency and power factor of the PSU in this Recommendation.

Table I.4 – Procurement requirements of China

% of rated load	20%	50%	100%
Energy efficiency	90%	94%	91%
Power factor	≥ 0.95	≥ 0.95	≥ 0.95

I.4 Certification requirements of China

CQC3178-2021 "Energy efficiency grades certification criteria for internal power supply" is a certification service jointly developed and launched by the China quality certification center (CQC), equipment manufacturers and Internet manufacturers. This business is applicable to embedded power supply of information technology equipment, telecommunication equipment, audio and video equipment and industrial equipment, aiming to promote the development of the power industry towards the direction of green energy saving.

The energy efficiency classification certification of embedded power supply is divided into seven levels, among which level I is the lowest level and level VII is the highest level.

Table I.5 – Certification requirements of China

115V internal non-redundant					
EE classification	Technical index	% of rated load			
		10%	20%	50%	100%
Level I	EE	-	81%	84%	80%
	PF	-	0.80	0.85	0.90
Level II	EE	-	85%	88%	85%
	PF	-	0.80	0.90	0.95
Level III	EE	-	88%	90%	87%
	PF	-	0.80	0.90	0.95
Level IV	EE	85%	90%	92%	89%
	PF	0.80	0.85	0.95	0.95
Level V	EE	88%	91%	93%	90%
	PF	0.80	0.90	0.95	0.96
Level VI	EE	90%	92%	94%	91%
	PF	0.80	0.95	0.95	0.98
220V internal non-redundant					
EE classification	Technical index	% of rated load			
		10%	20%	50%	100%
Level I	EE	-	83%	86%	82%
	PF	-	0.80	0.90	0.90
Level II	EE	-	87%	90%	87%
	PF	-	0.80	0.90	0.95
Level III	EE	-	90%	92%	89%
	PF	-	0.80	0.90	0.95
Level IV	EE	87%	92%	94%	91%
	PF	0.80	0.85	0.95	0.95
Level V	EE	89%	93%	95%	91%

Table I.5 – Certification requirements of China

	PF	0.80	0.90	0.95	0.96
Level VI	EE	91%	94%	96%	92%
	PF	0.80	0.95	0.95	0.98
220V internal redundant (low voltage output)					
EE classification	Technical index	% of rated load			
		10%	20%	50%	100%
Level II	EE	-	85%	89%	85%
	PF	-	0.80	0.92	0.95
Level III	EE	-	88%	92%	90%
	PF	-	0.80	0.92	0.98
Level IV	EE	87%	91%	94%	91%
	PF	0.80	0.92	0.98	0.99
Level V	EE	90%	94%	94%	91%
	PF	0.90	0.95	0.98	0.99
Level VI	EE	91%	95%	96%	92%
	PF	0.90	0.96	0.98	0.99
Level VII	EE	92%	96%	97%	93%
	PF	0.90	0.96	0.98	0.99
220V internal redundant (high voltage output)					
EE classification	Technical index	% of rated load			
		10%	20%	50%	100%
Level IV	EE	88%	91%	94%	91%
	PF	0.80	0.92	0.98	0.99
Level V	EE	91%	94%	96%	93%
	PF	0.90	0.95	0.98	0.99
Level VI	EE	92%	96%	98%	96%
	PF	0.90	0.96	0.98	0.99
Level VII	EE	93%	97%	99%	97%
	PF	0.90	0.96	0.98	0.99

Appendix II

Example of PSU for server testing

(This appendix does not form an integral part of this Recommendation.)

II.1 Test items

The test items of the PSU with AC input for the server are shown in Table II.1.

Table II.1 – Test item list

Number	Test item
1	Input voltage range
2	No-load power consumption
3	Energy efficiency
4	Input rated frequency and frequency fluctuation range
5	Power factor of different rated load
6	Total harmonic distortion of input voltage and current
7	Load distribution management

II.2 Test samples and data

In order to better understand the technical level of PSUs on the market, these test samples of PSUs for this test are provided by eight mainstream server manufacturers. They can represent the technical level of most PSUs on the market. The input voltage of PSU test samples is AC 220V and the rated frequency is 50 Hz.

The specific test results are shown in Table II.2 to Table II.6.

II.2.1 Test on input voltage range, input rated frequency and frequency fluctuation tolerance

Table II.2 – Test results

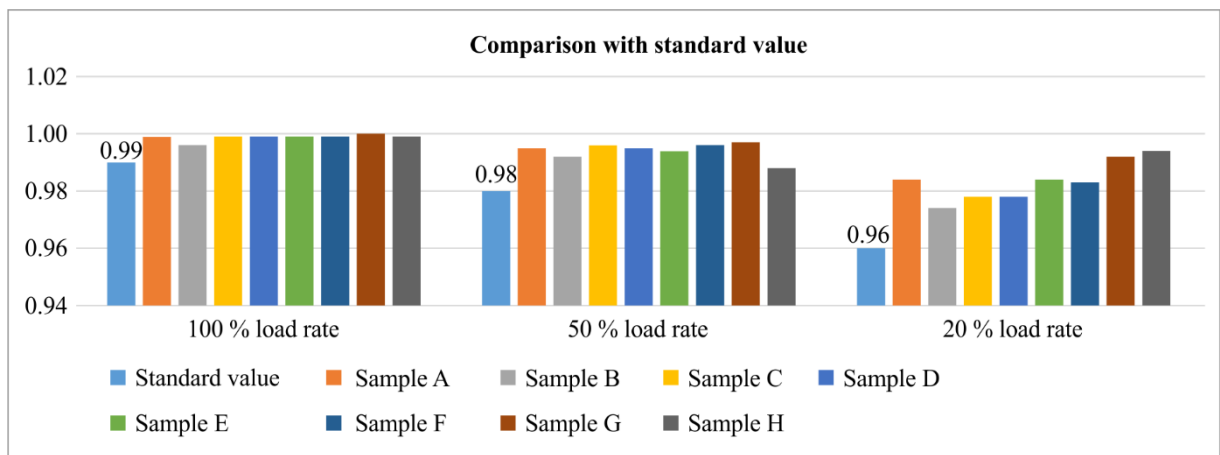
Test item	Input voltage range (V)	Input rated frequency (Hz)	Frequency fluctuation tolerance (Hz)
Sample A	176~264	50	45~55
Sample B	176~264	50	45~55
Sample C	176~264	50	45~55
Sample D	176~264	50	45~55
Sample E	176~264	50	45~55
Sample F	176~264	50	45~55
Sample G	176~264	50	45~55
Sample H	176~264	50	45~55

It can be seen that under the condition of input voltage range, input rated frequency and frequency fluctuation tolerance from Table II.2 respectively, all the PSU test samples can work normally.

II.2.2 Test on the power factor of different rated load

Table II.3 – Test results

Test item	Power factor of % rated load					
	100%	50%	40%	30%	20%	10%
Sample A	0.999	0.995	0.994	0.990	0.984	0.963
Sample B	0.996	0.992	0.989	0.983	0.974	0.944
Sample C	0.999	0.996	0.994	0.989	0.978	0.932
Sample D	0.999	0.995	0.992	0.986	0.978	0.935
Sample E	0.999	0.994	0.990	0.990	0.984	0.961
Sample F	0.999	0.996	0.994	0.990	0.983	0.947
Sample G	1	0.997	0.994	0.990	0.992	0.962
Sample H	0.999	0.988	0.991	0.994	0.994	0.925



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Figure II.1 – Comparison with standard value of power factor of different rated load

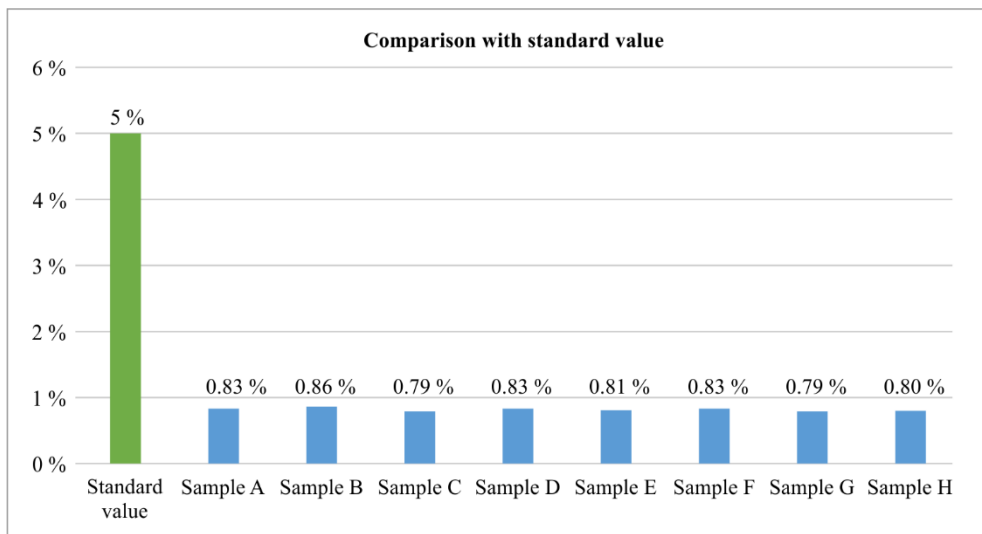
The power factor of PSU test samples is 100%, 50%, 40%, 30%, 20%, and 10% rated load respectively. From the test results, at a 100% load rate, the highest value of the power factor is 1, and the lowest value is 0.996. At 50% load rate, the highest value of power factor is 0.997, and the lowest value is 0.988. At 20% load rate, the highest value of power factor is 0.994, and the lowest value is 0.974.

Comparing the test results with the highest requirements of CQC3178-2021 for power factor in Appendix I, it can be seen that all PSU test samples are higher than the requirements.

II.2.3 Test on total harmonic distortion (THD) of voltage and current

Table II.4 – Test results

Test item	Total harmonic distortion of input voltage and current of different rated load							
	THD _u		THD _i					
	100%	No-load	100%	50%	40%	30%	20%	10%
Sample A	0.83%	0.79%	4.15%	7.11%	8.19%	9.91%	11.75%	15.05%
Sample B	0.86%	0.79%	7.93%	10.65%	13.37%	14.87%	15.22%	17.77%
Sample C	0.79%	0.79%	2.15%	3.51%	6.61%	9.91%	14.95%	21.78%
Sample D	0.83%	0.79%	4.58%	5.32%	5.42%	6.01%	9.13%	18.96%
Sample E	0.81%	0.79%	4.28%	6.50%	6.60%	11.32%	9.82%	12.27%
Sample F	0.83%	0.82%	4.52%	6.24%	6.55%	7.23%	8.60%	11.39%
Sample G	0.79%	0.79%	2.43%	3.94%	4.47%	5.38%	7.22%	14.46%
Sample H	0.80%	0.81%	4.72%	7.83%	8.43%	8.59%	11.09%	40.85%



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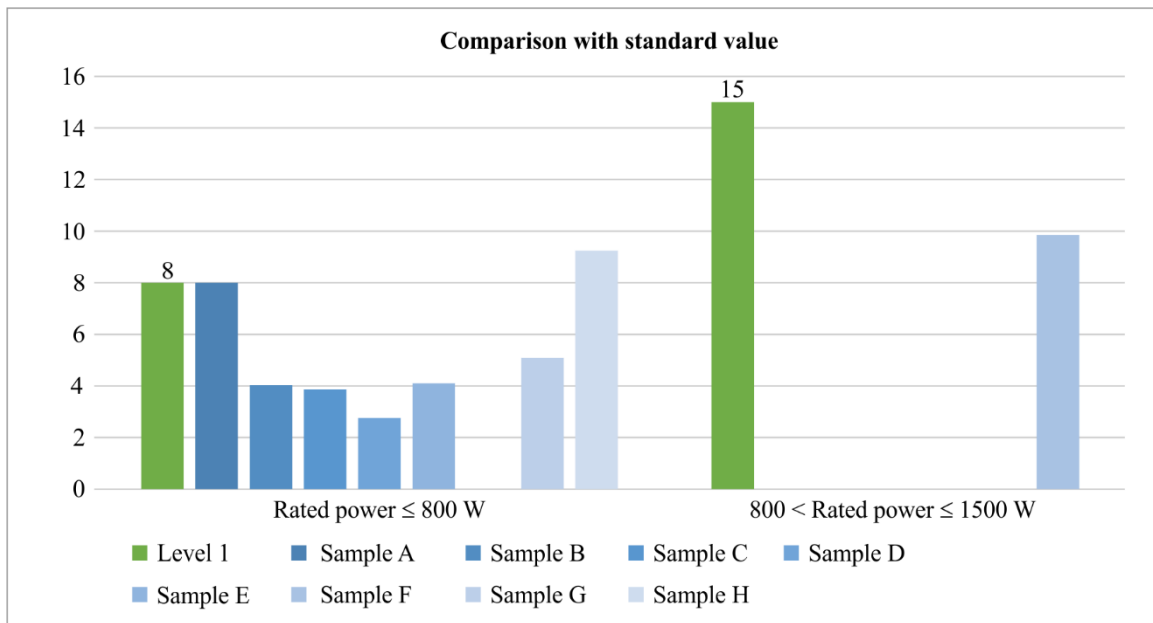
Figure II.2 – Comparison with standard value of total harmonic distortion of input voltage

The requirement of total harmonic distortion of input voltage should not be greater than 5% in GB/T 14549-1993 of China, which is stricter than the compatibility level specified in [IEC 61000-2-2]. All PSU participants in the test can meet the requirement, with the maximum being 0.83%, and the minimum being 0.79%.

II.2.4 Test on no-load power consumption and EE of different rated load

Table II.5 – Test results

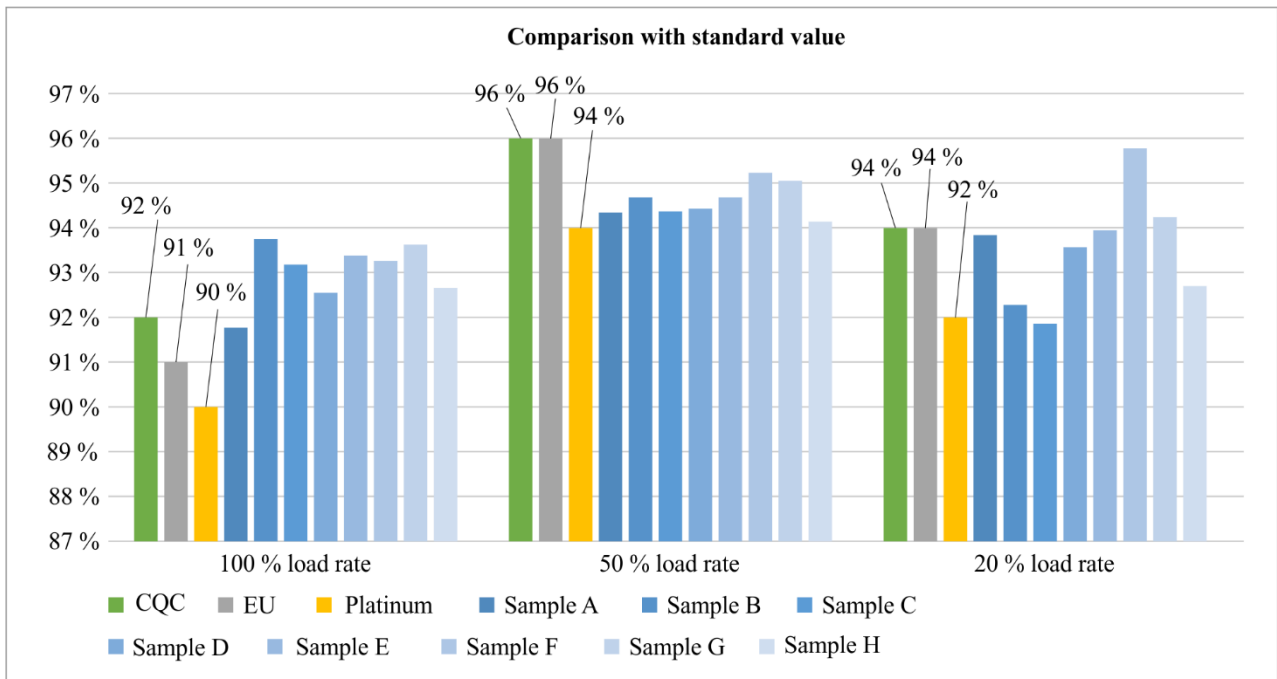
Test item	No-load power consumption(W)		EE of % rated load					
	Rated power \leq 800W	800 < rated power \leq 1500W	100%	50%	40%	30%	20%	10%
Sample A	8.014		91.77%	94.34%	94.41%	94.27%	93.84%	90.78%
Sample B	4.033		93.75%	94.68%	94.32%	93.44%	92.28%	88.73%
Sample C	3.864		93.18%	94.37%	94.56%	93.93%	91.86%	87.02%
Sample D	2.760		92.55%	94.43%	94.87%	94.61%	93.57%	89.66%
Sample E	4.100		93.38%	94.68%	94.60%	94.15%	93.95%	91.7%
Sample F		9.843	93.26%	95.23%	96.01%	95.89%	95.78%	92.35%
Sample G	5.085		93.63%	95.05%	95.10%	95.15%	94.24%	90.99%
Sample H	9.246		92.66%	94.14%	94.06%	93.58%	92.70%	87.79%



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Figure II.3 – Comparison with standard value of no-load power consumption

Most of the eight PSU test samples participating in the test can meet the requirements of 1% of rated power for no-load power consumption. For PSU with rated power \leq 800 W, the maximum of no-load power consumption is 9.246 W and the minimum is 2.760 W, and for 800 < rated power \leq 1500 W, the no-load power consumption is 9.843 W.



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Figure II.4 – Comparison with a standard value of EE of different rated load

Compared with the energy efficiency (EE) requirements in Appendix I, it can be seen that among the eight PSU samples participating in the test, all the samples can meet the requirements of platinum level in 80 PLUS with 100% and 50% load rate. With a 20% load rate, only one sample cannot meet the platinum level. Although it can be seen from comparative analysis that the requirements of CQC3178-2021 and EU ecodesign 2023 are higher than the test results, it should be noted that these two documents were released a few years later than the test results, and the technical level of PSU has also improved in these years.

II.2.5 Test on load distribution management

Table II.6 – Test results

Test item	Load distribution management: load sharing mode			
	The imbalance of output current sharing			
	of 100% rated load		of 50% rated load	
Sample A	–	–	–	–
Sample B	–1.64%	1.64%	–0.98%	0.98%
Sample C	–0.34%	0.34%	–0.59%	0.59%
Sample D	–0.12%	0.12%	–0.01%	0.01%
Sample E	–1.64%	1.64%	–0.30%	0.30%
Sample F	–0.56%	0.56%	–0.21%	0.21%
Sample G	–3.41%	3.41%	–1.70%	1.70%
Sample H	–0.31%	0.31%	–0.08%	0.08%

Bibliography

- [b-ITU-T L.1330] Recommendation ITU-T L.1330 (2015), *Energy efficiency measurement and metrics for telecommunication networks*.
- [b-ITU-T L.1350] Recommendation ITU-T L.1350 (2016), *Energy efficiency metrics of a base station site*.

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