# Technologies Supporting Reliability of Power System Products

Naohiko Shiokawa Hiroyuki Hanaoka Hiroyuki Kaneko Tetsuya Kobayashi

## 1. Introduction

In modern society, various devices support people's lifestyles. The development of these devices is essential in order to realize a safe, secure, convenient and comfortable society. Along with safety and environment-friendliness, the "reliability" of devices is an important element demanded by society. No matter how low price or highly functional a device is, it will not be accepted by society if it lacks reliability. High reliability is particularly demanded of devices used in social infrastructure such as energy, water, transportation, medical and communication.

Sanyo Denki's power system products have contributed to improving the reliability of communication systems in UPS, CVCF, emergency power generation equipment and other power sources for communication. Moreover, in recent years, we are also providing devices with high reliability for PV inverters, grid management units and other power conversion equipment.

This paper provides a detailed introduction of technologies supporting the high reliability of power system products, as well as their application products.

## 2. Actions Towards Achieving Reliability

### 2.1 The definition and evaluation of reliability

According to JIS Z 8115 (2000) "Dependability (reliability) terminology" , reliability is defined as "a characteristic of an item to perform a required function under given conditions for a given time interval" . In this case, "item" is a generic term for component, material, module, device, system, and so on. As the definition of "reliability" is described as "characteristic", it is a qualitative property. However, when evaluating reliability, we must judge based on quantitative numerical properties. "Degree of reliability", "failure rate", "MTBF" and "MTTF" are widely known as means of quantitatively evaluating reliability. Sanyo Denki's power system products are also evaluated using these quantitative values.

### 2.2 Actions towards reliability in power system products

#### 2.2.1 Reliability design and design review

In order to design products with the required reliability, it is important to clarify the three factors: defined conditions, designated times, and required functions. In other words, these are the way a device is used and the environmental conditions, the design life, and the most important functions a device should perform. The abovementioned 3 key factors are discussed and clarified in a design review (hereinafter referred to as "DR" ), held during the product design/development phase. FTA and FMEA are also performed during DR to clarify failure factors and effects in advance and discuss countermeasures to prevent such failures.

The components and material used in Sanyo Denki's products must pass our internal component certification test. The reliability of the components used in products are also discussed during DR.

If a power system product breaks down, it is repaired then reused. These types of devices are called "Repairable-types" and there is a need to consider their reliability, including the maintainability aspect. During DR, a discussion is held as to whether ample consideration has been made regarding preventive maintenance such as selection and replacement procedures of periodic replacement components, as well as breakdown maintenance such as failure investigation and recovery procedures.

#### 2.2.2 Reliability verification tests

In the Power Systems Division, reliability is verified by doing the following tests on the products being developed, designed, and manufactured as well as the material and components used.

(i) Component reliability test in component certification
(ii) Reliability test in developed product evaluation test
(iii) Reliability test in developed product quality assurance test.
(iv) Reliability test for products moved into mass production
(v) Screening test for the initial failure removal of mass production products

### 2.3 Design technologies increasing reliability

This section introduces the typical design technologies increasing reliability.

#### 2.3.1 Reducing the number of components

The failure rate of products configured from N number components with a failure rate of $\lambda$ is $\lambda \times N$. This means that reducing the number of components used in a product will also reduce the failure rate.

#### 2.3.2 Reducing the effect of failure factors

Temperature, voltage, current, humidity, machine stress and chemical substances are some of the factors affecting the failure rate of electronic components. Depending on the conditions of use, it is necessary to reduce the effects of these factors.

#### 2.3.3 Derating

Component failure rate can be reduced if a component is used under conditions whereby rating is multiplied by the surplus rate or safety rate. This is often applied for the voltage, current and temperature conditions of electronic components.

#### 2.3.4 Redundant design

Even if one component or module fails, if spares are provided which compensate the failed portion, reliability is dramatically improved. Redundant design is the most common technique used to increase reliability.

#### 2.3.5 Consideration of maintenance work

Repairable-type devices must take ease of maintenance work into consideration. Depending on the device, consideration must be made at the design phase so that preventative maintenance does not stop the device's operation and can be performed safely in a short period of time.

The next chapter introduces the details of the technologies supporting the reliability of power system products.

## 3. Technologies Supporting the Reliability of Power System Products

### 3.1 Technologies supporting the reliability of small capacity UPS

Creativity is required for technologies to raise the reliability of small capacity UPS, which is a highly cost-competitive area.

#### 3.1.1 Reducing the number of components

Each component has a certain failure rate, and the failure rate of the overall equipment is an accumulation of these, therefore it is obvious that reducing the number of components will increase the reliability of equipment. It will also lead to cost reduction. As such, there is a need to use even higher level techniques for improving reliability after reducing the number of components in individual equipment. The following are some specific ways of reducing the number of components.

・Integrating the control circuit into a microprocessor
・Simplifying the drive circuit
・Integrating power components

Compared to the “SANUPS ASC” 1 kVA of ten years ago, the latest “SANUPS A11F” 1 kVA has around half the number of components.

#### 3.1.2 Parallel redundant system

Parallel redundancy of equipment is a very effective way of improving reliability. As shown in Fig. 1, parallel redundancy involves connecting 2 or more of the same pieces of equipment in parallel and continuing power supply from one of these if failure occurs on the other. The number of components increases compared to a single UPS, however, reliability improves dramatically according to the logic of parallel systems.

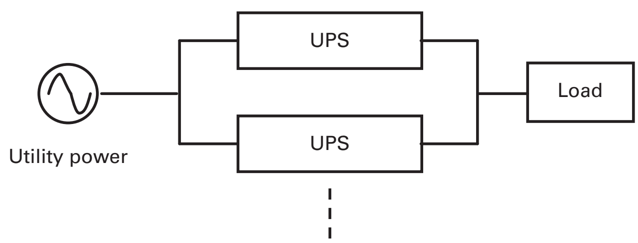



Fig. 1: Parallel redundant system

In Sanyo Denki's small capacity UPS, the “SANUPS ASE-H” and “SANUPS A11J” (Fig. 2) are of a parallel redundant design.

Fig. 2: “SANUPS A11J” (stand-alone)

Of these, the unit capacity of the “SANUPS A11J” is 5 kVA and can be connected in a parallel connection comprising of up to 4 units. When configuring as a N+1 parallel redundant system, there must be enough surplus for 1 unit, therefore in a 4-unit parallel connection, the system is configured as 15 kVA equipment. The UPS outputs AC, therefore in order to connect UPS-to-UPS outputs in parallel, the high-level control of each UPS output voltage is necessary. Using Sanyo Denki’s own digital control technology, the “SANUPS A11J” has achieved high-speed control and contributes to the higher reliability of systems.

### 3.1.3 Uninterrupted power transfer switch

Parallel redundant system is a method to increase the reliability of the UPS itself, however, uninterrupted power transfer switches (generally referred to as “STS” or “Static Transfer Switch” ), may be used in order to increase the reliability of the system itself. As shown in Fig.3, power is brought in from different power grids and supplied to load through STS. In this system, the STS detects abnormalities in each power source and can transfer to the route without an abnormality.

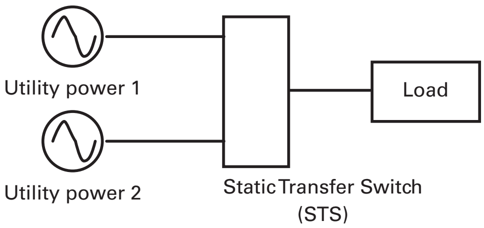



Fig. 3: A system using a semiconductor transfer switch

The STS is shared in this system, however its configuration is simple and there are only a small number of parts, making it highly reliable. Sanyo Denki has the “SANUPS S11A” (Fig. 4) prepared as an STS product.

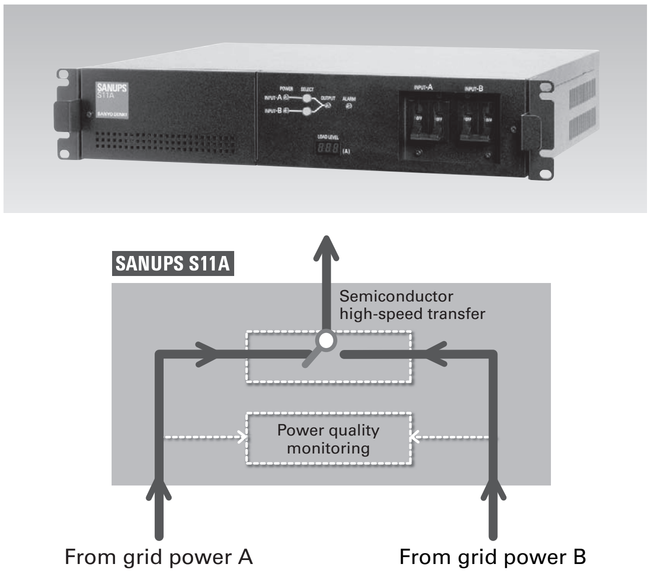



Fig. 4: “SANUPS S11A”

The “SANUPS S11A” switches between the two inputs, grid A and grid B, within 3 msec by having independent power monitoring circuits and a hybrid switch combining a semiconductor and a relay. To increase reliability further using this product, a UPS may be added to each grid, as shown in Fig. 5.

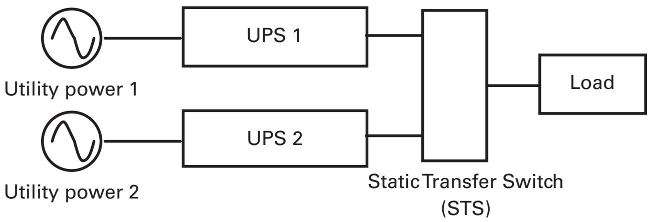



Fig. 5: A highly reliable system using STS

## 3.2 Technologies supporting the reliability of mid- and large-capacity UPSs

Mid- and large-capacity UPSs are often used for the essential load in places such as data centers where even a split-second power supply stop is unacceptable. This section introduces medium/large capacity UPS system configurations with a focus on reliability of power supply to the load.

### 3.2.1 Stand-alone systems [with utility power (bypass)]

Sanyo Denki’s mid- and large-capacity UPSs come in two types of power supply system: the on-line type and the parallel processing type. However, by adding utility power (bypass) to both of these types, the reliability of power supply to the load is increased.

In the on-line type UPS such as the "SANUPS A23C", if the inverter fails to function properly, the power circuit is switched to the bypass circuit automatically to continue supplying power to the load (Fig. 6). In the parallel processing type UPS such as the "SANUPS E23A", the utility power (bypass) and inverter output operate in parallel during normal times, and in the event of inverter failure, power is supplied from utility power through the bypass circuit (Fig. 7).

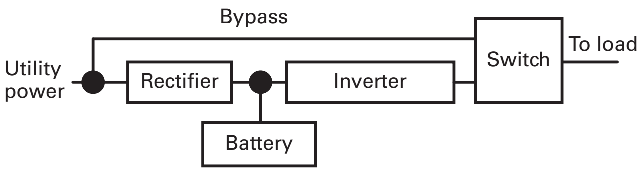



Fig. 6: Stand-alone system (on-line type)

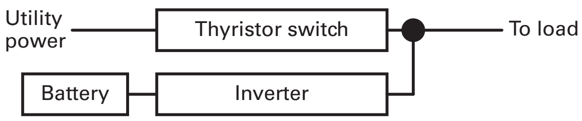



Fig. 7: Stand-alone system
(parallel processing type)

### 3.2.2 Parallel redundant system

Here we will introduce the "SANUPS E33A" as an example of our large capacity parallel redundant UPS systems. The "SANUPS E33A" is the first parallel redundant UPS using parallel processing in the industry. To achieve a parallel redundant UPS using parallel processing, it is essential to have technology that detects any abnormalities in utility power at high speed and high accuracy, as well as control technology that prevents circulating current between the UPSs connected in parallel and between the utility power and the inverter. The "SANUPS E33A" meets these requirements by using the latest digital control technology (Fig.8).

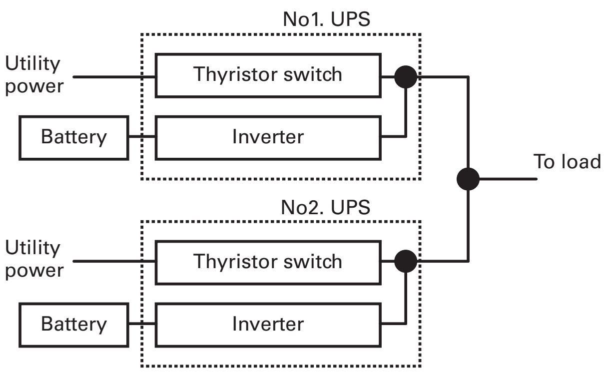



Fig. 8: Parallel redundant system
(parallel processing type)

### 3.2.3 Standby redundancy system

A stand-by redundant system consists of two on-line type UPSs, a regular UPS and a spare UPS. Under normal circumstances, power is supplied to the load by the regular UPS, and in the event of failure or during maintenance and inspection, the spare UPS takes over. This system can be configured with the single-unit system UPS with little change of its standard specifications. This system also has a common spare system which consists of multiple regular UPSs and 1 spare (Fig. 9).

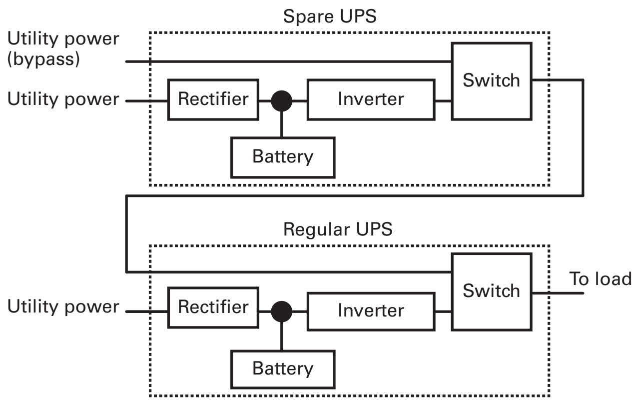



Fig. 9: Standby redundancy system
(on-line type)

### 3.2.4 Redundancy technologies in stand-alone systems

Our RMA is a UPS which has achieved standby redundancy within a stand-alone system. The RMA has a two-way converter besides the normal inverter and rectifier. The two-way converter is capable of inverter operation and rectifier operation and functions as a spare inverter and spare rectifier. Our standby redundant system is built at the conversion unit level.

It has significant advantage over normal standby redundant systems in regards to economic performance and installation space. It is also possible to build a standby redundant system using RMA, which results in an even higher reliability system (Fig. 10).

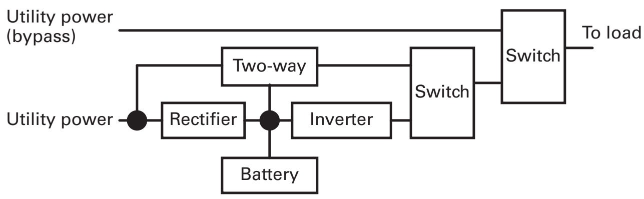



Fig. 10: High reliability UPS system

### 3.3 Technologies supporting emergency power generator

The most important function of an emergency power generator is that its motor and generator, which are stopped during normal conditions, reliably start up and supply power during a power outage. To achieve this, it is necessary to maintain the fuel, lubrication oil, cooling water, battery and control circuit so that the generator is always in a state where it can start up immediately. As such, the generator has cooling water insulation, automatic periodic maintenance operation, and failure detection functions. Sanyo Denki also offers communications companies a diesel engine generator with a diagnosis function, in which these functions are enhanced (Fig. 11).

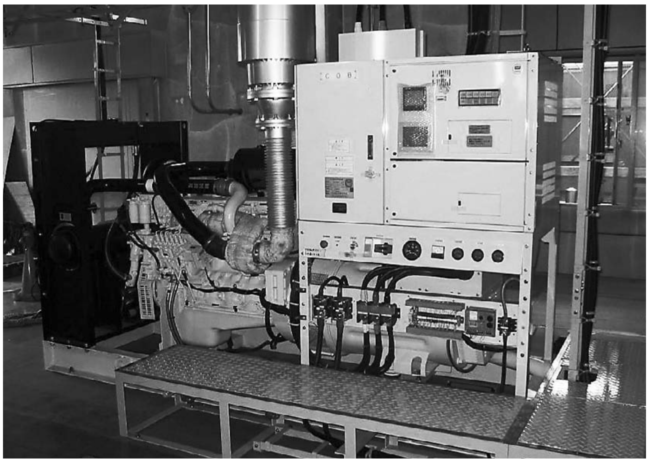


Fig. 11: Emergency diesel engine generator with a diagnosis function

#### 3.3.1 Diagnosis function

The diagnosis function is a function which not only detects equipment failure, but also helps determine the location and the cause of the failure. It enables early recovery of the equipment in the case of failure.

#### 3.3.2 Periodic priming function

The periodic priming function turns the starter motor with the fuel injection stopped and prevents the inside of the motor from oil film shortage. At the same time, it also confirms the normality of the battery and starter motor. Also, because the motor is not operated, fuel is not consumed and exhaust gas is not discharged, making this a function which contributes to the alleviation of environmental burden.

#### 3.3.3 Maintainability

Emergency power-generation equipment is used for over 20 years from installation. Periodic maintenance is required numerous times, therefore ease of maintenance work is a key focus. In the control panel, which has many components for periodic replacement, Sanyo Denki has adopted plug-in type components, common components and units in order to improve maintainability. Also, for outdoor cubicle power-generating equipment, mobile power supply vehicle and other power-generating equipment housed in a package, consideration has been made towards door/cover arrangement, securing space, etc., in order to allow the inspection/maintenance of all component parts.

## 4. Conclusion

This concludes our introduction of the technologies which support reliability of power system products.

In recent years, there is a tendency for the systems which use power system products to be more complex. The "reliability" of devices which support such complex systems has expanded from the limited definition of making equipment "hard to fail" to being able to recover "availability" swiftly in the unlikely event failure does occur. This is due to, based on the assumption that deterioration and failure of devices is unavoidable, the emphasis has shifted to maintaining the overall system in a satisfactory state even during failure and not hindering the practical application.

In order to increase availability, in addition to including the reliability technologies introduced in this paper in products, management technology such as provision of information relating to product operation/maintenance, document control, operation/maintenance planning support and worker training, etc., is required.

Sanyo Denki would like to continue providing users with products of the desired high reliability and contributing to the realization of a safe, secure, convenient and comfortable society.

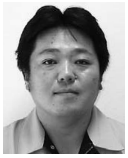
Documentation

Yasuyoshi Fukui "Reliability Science"

**Naohiko Shiokawa**
Joined Sanyo Denki in 1989.
Power Systems Division, 3rd Design Dept.
Worked on the development and design
of power supplies.

**Hiroyuki Hanaoka**
Joined Sanyo Denki in 1988.
Power Systems Division, 2nd Design Dept.
Worked on the development and design
of power conversion devices.

**Hiroyuki Kaneko**
Joined Sanyo Denki in 1993.
Power Systems Division, 1st Design Dept.
Worked on the development and design of UPS.



**Tetsuya Kobayashi**
Joined Sanyo Denki in 2002.
Power Systems Division, 3rd Design Dept.
Worked on the development and design of rotary
type power-generating equipment.