UPS Suitable for Production Equipment Field, "SANUPS E"

Yoshiaki Okui

1. Introduction

Uninterruptible power supplies (UPS) have found widespread application in the communications sector, where power cuts can cause serious problems for the community, and in computers, which tend to be susceptible to changes in the power supply. But power supply interruptions also have the potential to weak havoc in manufacturing, if it leads to a decline in yield and failure to meet the tight production schedules that are commonplace today. In one instance, a manufacturer sustained a loss in excess of 10 billion yen because of a power failure. Not surprisingly, then, manufacturers are looking at devices that address interruptions in commercial power supply. In some cases, manufacturers are introducing devices to control instantaneous voltage drops, in addition to UPS. These devices have characteristics that differ from those of UPS. They specialize only in compensating for instantaneous voltage drops, which are namely brief drops in voltage and which are one of the kinds of problems that can occur with commercial power supply. UPS deal not only with instantaneous voltage drops but with other problems as well, including power failure. Both solutions presently have their strengths and weaknesses and both are being introduced for use with manufacturing equipment.

This paper considers the realities of instantaneous voltage drops and power failures and the progress that has been made with devices to control instantaneous voltage drops and UPS. It will also introduce the parallel processing method UPS, which is a new method believed to be ideal for power supplies for manufacturing equipment.

2. Realities of Instantaneous Voltage Drops and Power Failure

The definition of a voltage drop is as follows: "A phenomenon in which the voltage drops around a breakdown point until the point is detected by a protection relay and removed from the electric power system with the breaker, when a breakdown occurs because, for example, of lightning striking the power transmission line, in an electric power system" (1). The standard in the personal computer industry with respect to instantaneous voltage drops is as follows: "The voltage of the business AC electric power supplied to the equipment and the system drops or is temporarily intercepted for a period ranging from several milliseconds to 2 seconds" (2).

2.1 Details

The problem concerning instantaneous voltage drops has long been examined and was discussed by the Electric Power Use Base Reinforcement Gatherings, which was set up as a private advisory body to the Secretary Agency of Natural Resources and Energy. This organization put together a report in May 1987. The Gathering reported that instantaneous voltage drops were a physically inevitable phenomenon and to prevent any impact, measures on the load equipment side or the customer side are sensible. The report went on to say that it was important for the power supplier, the equipment manufacturer, and the government to continue to work closely on technical studies. Since then, a study of instantaneous voltage drops has been conducted to explain the mechanism by which they are generated and their cause, the spread as well as the annual average frequency of voltage drops (3).

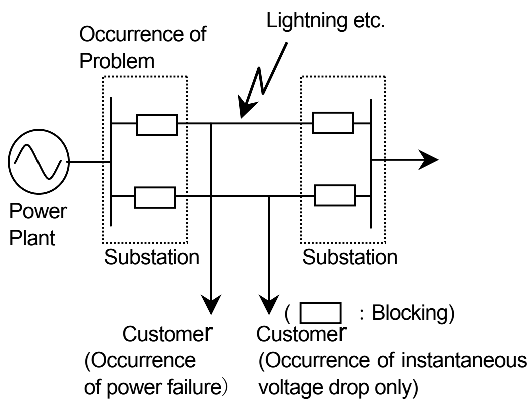


Fig.1 When the Breakdown Point Is Removed

2.2 Generation Mechanism

When a breakdown (mainly caused by flashover by lightning) occurs because of lightning striking a power transmission line in an electric power system, the protective relay that was set up for each item of equipment such as the power transmission line detects the problem point at high speed to maintain safety in the power system and block the problem from the electric power system using the breaker. Fig. 1 shows what happens when the problem point is removed. When the breakdown occurs, an instantaneous voltage drop occurs for both customer A and customer B until the protection relay begins to operate. The breakdown point is removed between 0.07 to 0.3 seconds later, with the length of time involved differing depending on the voltage class of the power transmission line where the breakdown occurred. At this time, even customer B, who is receiving electricity from another line during this period, experiences an instantaneous voltage drop, with the supply returning to normal when the problem point is removed. The impact of this spread of the instantaneous voltage drop can be extensive in a high voltage class system and occasionally extends over several prefectures. Although customer A experiences a black out as the problem line is cut off, the problem power transmission line is restored automatically in approximately 1-2 minutes. A device to control an instantaneous voltage drop is of no help when a power failure occurs, and a UPS is necessary.

Breakdowns in power transmission lines are mostly caused by natural phenomena such as lightning. Many instances of lightning striking a power transmission line do not involve direct hits to the line but to the ground wire, and a significant current flows from the ground wire to the earth through the iron pole. At this time, the iron pole potential rises because a large current flows through the iron pole, and insulation breakdown occurs between the power lines. This phenomenon is called a flashover(4). Consequently, the instantaneous voltage drop occurs because the power line experiences a ground fault.

2.3 Annual Frequency of Instantaneous Voltage Drops

Fig. 2 shows the estimated average occurrence of instantaneous voltage drops. The frequency of the instantaneous voltage drop differs depending on the region and the month. The vast majority of causes of instantaneous voltage drops are the result of thunderstorms, and the frequency generally rises in regions that experience more thunderstorms. Moreover, the monthly frequency is concentrated on the summer thunderstorm season and we also expect it to increase in the thunderstorm region by the Sea of Japan in winter. The frequency of instantaneous voltage drops (with a drop of more than 10%) per consumer is 12 time per year (national average). This doubles in regions that experience more thunderstorms and is halved in regions subjected to fewer such storms. The natonal average level of power failures is 0.5 times/year.

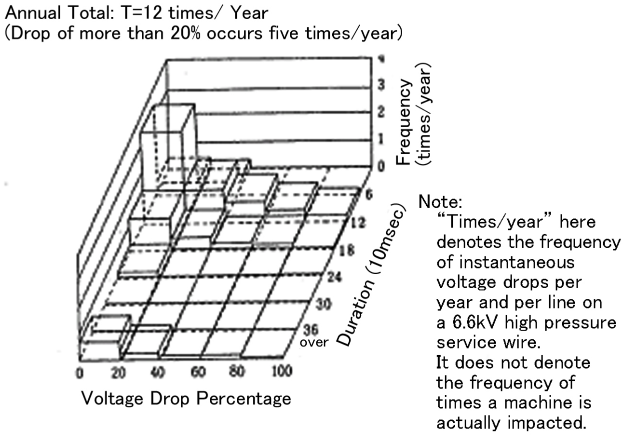


Fig.2 Instantaneous Voltage Drops Per Customer (National Average)

3. UPS and Devices to Control Instantaneous Voltage Drops

3.1 UPS Types and Circuit Systems

The points of comparison of UPS with devices that control instantaneous voltage drops are the circuit system, the backup time, maintainability, and cost-effectiveness. A number of different circuit systems have been suggested for both UPS and devices to control instantaneous voltage drops. For UPS, they include continuous inverter power supply systems and continuous commercial power supply systems, when roughly divided by basic circuit composition as shown in Fig. 3.

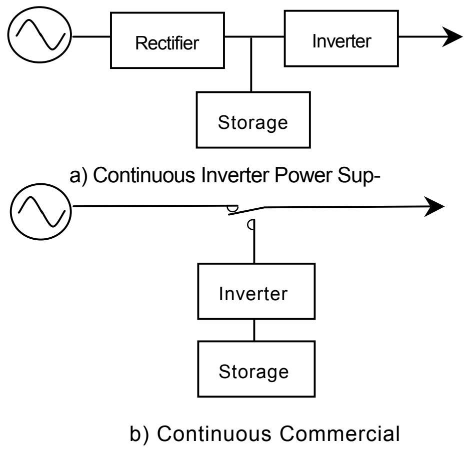


Fig.3 Types of UPS

The continuous commercial power supply system is a small and low-cost UPS because it has only one electric power converter, and power loss at normal operation can be suppressed since it receives a commercial power supply. However, an instantaneous breakdown is inevitable because backup operation starts after the abnormality is detected when the power supply experiences the problem. Its application may therefore be limited depending on the load system. On the other hand, the continuous inverter power supply system UPS can provide high-quality electric power without an instantaneous breakdown at any time, even at the time of power trouble, because it is converting commercial power through two electric power converters of a rectifier and an inverter during normal use. The power loss, however, is larger because it uses two power converters. Although the continuous inverter power supply system UPS is more widely used in the communications and computer industry, the market is increasingly requiring higher efficiency (energy saving) and control of the initial investment because of environmental concerns. Therefore, other systems like the parallel processing system (5) and the line interactive system (6), which are positioned somewhere in between the two systems described above, have recently been proposed. SANYO DENKI has released a parallel processing system UPS called SANUPS E, which features no-brake transfer. It will be described below(7). A line interactive type is becoming more popular with small UPS capacities of 10kVA or less, while the parallel processing system, the continuous commercial power supply systems, and the line interactive system, are finding growth application in the mid and large capacity UPS market.

3.2 Types and Features of Devices to Control Instantaneous Voltage Drops

The circuit structure of a device to control instantaneous voltage drops includes series compensating systems, transformer tap switch systems, and continuous commercial power supply systems, as shown in Fig. 4. Many of these systems use capacitors as storage devices. The series compensating system stabilizes the voltage supply to the load by generating a voltage that compensates for the voltage drop with an inverter when an instantaneous voltage drop occurs, and adds to the dropped power-supply with the series. The duration of compensation is short because the energy stored in a capacitor is used as the power supply of the inverter. As for the transformer tap switch system, a storage device is unnecessary in principle, since it switches the transformer secondary tap at high speed in response to the voltage drop, but the maximum voltage drop is about 60%. In other words, these series compensating systems and transformer tap switch systems cannot support no-load power supply (a voltage drop of 100%). The circuit structure of the continuous commercial power supply system is the same as that of UPS excluding the storage device. In this case it is possible to support no-load power supply but it is not possible to deal with power failure since it specializes in providing compensation for a short period of time.

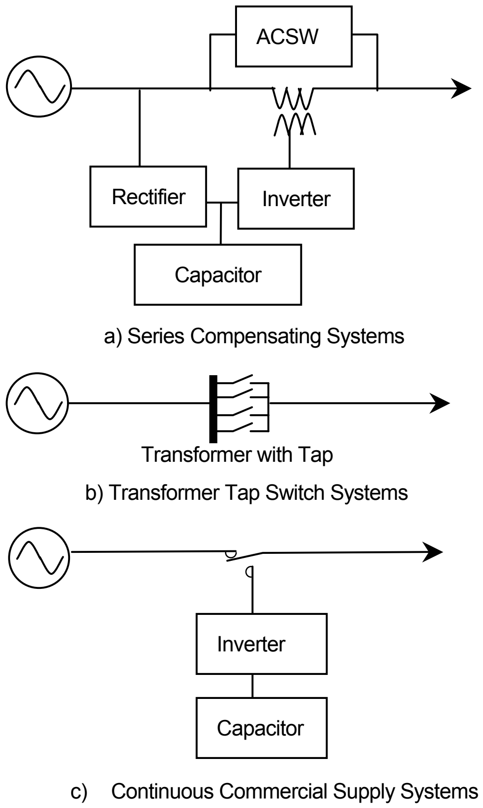


Fig.4 Types of Devices to Control Instantaneous Voltage Drops

These devices aim to achieve cost-effectiveness as well as simple circuits based on the idea of miniaturizing and valuing efficiency. Basically, then, commercial power supply is used for normal operation. For storage devices, easy maintenance and installation space are valued, and many of the devices aim to achieve early backup (0.01-2 seconds) by limiting the compensation providing for an instantaneous voltage drop, as described above. This reflects a concern for profitability on the production site and also the preferred approach of adopting a clear-cut attitude to problems caused by power failure, which occur with relatively low probability. Moreover, it is better if no maintenance is required, to avoid production line stoppages So devices to control instantaneous voltage drops employ the minimum circuit and structure to needed compensate for an instantaneous voltage drop. That makes a continuous inverter power supply system and lead storage battery unsuitable, but a combination of continuous commercial power supply system and capacitor can do the job. In this case, there is no difference between the circuit structure of the UPS and the instantaneous voltage drop control device, and the difference is the storage device. In general, the most popular storage device used with UPS is a lead storage battery. The lead storage battery is suitable for long-term backup since the energy density is as high as approximately 100 times that of an electrolytic capacitor. However, a general-purpose lead storage battery requires greater maintenance because its life is comparatively short (about five years). For this reason, devices to control instantaneous voltage drops that use a capacitor tend to need to emphasize ease of maintenance and installation space at the production sites. Recently, there have also been more cases in which the electric double layer capacitor with high energy density (About 20-30 times that of an electrolytic capacitor) is adopted. However, the lead storage battery is cheaper than a current electric double layer capacitor because it is in such widespread use. Moreover, special attention is needed when these latest storage devices are used. Although the capacitor may give the impression it needs no maintenance for ten years, it can require maintenance if the selection is mistaken since depends on its surroundings. In contrast, the lead storage battery also is also associated with a short life but there are long-life products (officially 13-15 years). However, the storage battery used with UPS does not last as long as the official life because it has a high rate electrical discharge (the life is assumed to be 9-12 years in 2C electrical discharge in the controlling valve type fixed lead storage battery). So if installation space is available secured, no maintenance can be assumed for about ten years even if the continuous commercial power supply system and long-life lead storage battery are combined. In this case, use of the lead storage battery makes more economic sense than using the electric double layer capacitor. And it also becomes possible to support not only instantaneous voltage drops but also power failures. Power failures occur with higher probability and it is better to deal with them cost-effectively, as described in Section 2. We depend heavily on technological progress in the storage device, and it will be important to respond to market trends in the future. As for the electric double layer capacitor, the fact that it does not use heavy metal is appealing, and it has potential if the energy density and the cost problems can be improved. The secondary battery that contains the lead storage battery is in the same position, and further improvements in easy of maintenance, cost, energy density and output density would be welcome. Table 1 shows a summary of storage devices.

Table 1 Comparison of Storage Devices

	Back Up Time	Easy Maintenance	Installation Space	Price
Electrolytic Capacitor	△ (Only Voltage Drop)	○	○	○
Electric Double Layer Capacitor	△ (Only Voltage Drop)	○	◎	×
Lead Storage Battery	◎	△ (5 Years of Life)	×	◎
Lead Storage Battery (Long Life Product)	◎	○	×	○

Note) Comparison with a backup time of 1 sec. for a capacitor and 5 min. for a storage battery.

Another storage device can be found in the instantaneous voltage drop control device using the flywheel system. Many of the main circuit structures of these instantaneous voltage drop control devices use continuous commercial power supply systems.

4. Characteristics of Parallel Processing System UPS

We have developed a parallel processing system UPS called SANUPS E (we market this product as a hybrid type UPS without momentary power breaks), which is more efficient than the continuous commercial power supply system although it has a similar circuit structure, as described above. This section describes the features of this UPS, and explains why this product is suitable for use with power supplies for manufacturing equipment.

4.1 Basic Structure

The parallel processing method UPS is a hybrid UPS with a simple structure in which the functions of an active filter, a charger, and an inverter exist in one power conversion system.

Fig. 5 shows the basic structure of this device.

The power converter is connected to a commercial power supply in parallel as shown in the figure. In normal use, the harmonic current with which the load is generated is controlled using the active filter function while supplying power from the commercial supply to the load. The charge in the storage battery is simultaneously processed in parallel by the charging function.

As for the supply system to the load, UPS is operated in a state of “power from the commercial supply, quality from the inverter.” Since only the “quality” amount goes through the power converter in normal operation, the power loss is rapidly diminished and the UPS is able to supply power very effectively to the load, in comparison with the continuous inverter power supply system.

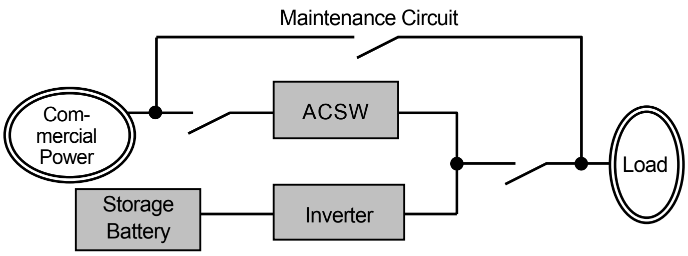


Fig.5 Basic Structure of The Parallel Processing System UPS

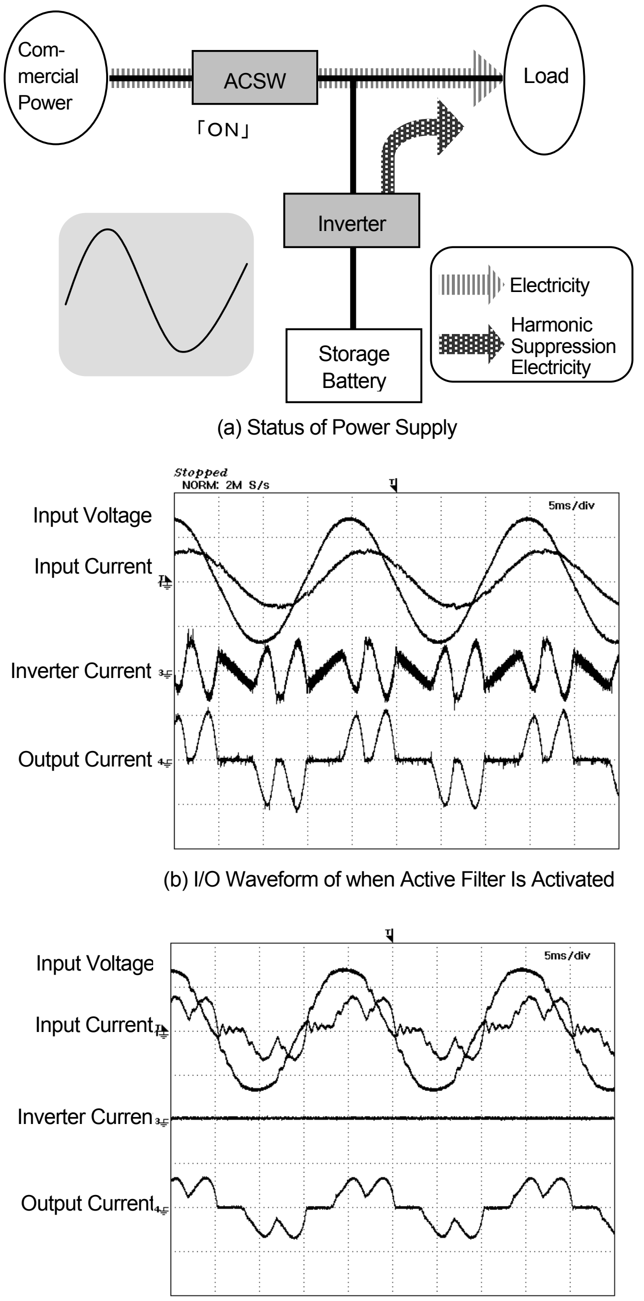
Moreover, it is a highly reliable UPS in which the commercial power supply is cut off at once when a problem occurs. The power converter is operated using an inverter to supply power to the load with no momentary breakdown[8] The basic operation is explained next.

4.2 Basic Operation

(1) During normal operation
(Commercial parallel supply)

During normal operation, the power converter operates as an active filter and a charger while supplying power from the commercial power supply to the load through ACSW, as shown in Fig. 6(a). Therefore, the control of the harmonic current generated from the load equipment and compensation for invalid power are implemented, and the input current is controlled so that the sine wave and the power factor become almost one.

Fig. 6(b) shows the I/O waveform at this time. The waveform when the active filter function is off is shown in Fig. 6(c).



(a) Status of Power Supply

(b) I/O Waveform of when Active Filter Is Activated

(c) I/O Waveform of when Active Filter Is NOT Activated

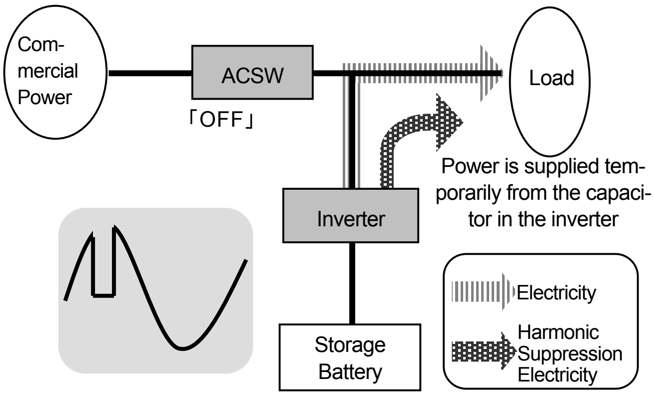
Fig.6 Operation and Waveform of The Commercial Parallel Power Supply

The input commercial power supply is distorted when the active filter is not functioning.

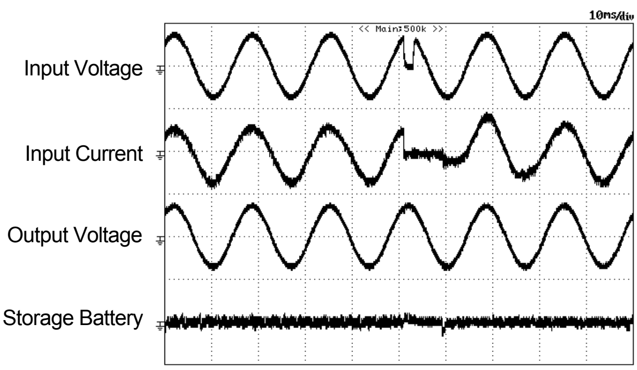
In the continuous commercial power supply system, because this function is not provided, it is possible that other equipment connected to the same system are influenced.

(2) When AC input is abnormal

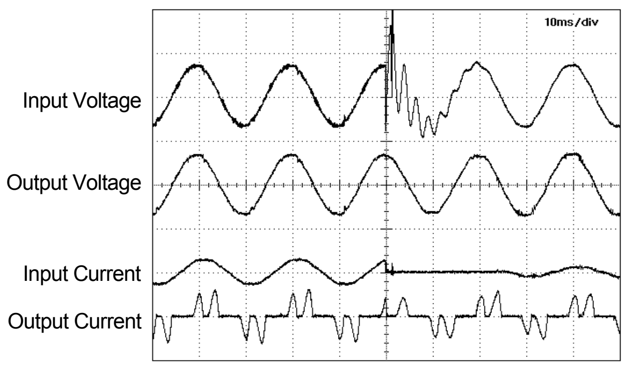
ACSW is turned off immediately the AC input has a problem, as shown in Fig. 7(a), and power is supplied to the load temporarily with no momentary breakdown by the electrolytic capacitor in the inverter.



(a) Status of Power Supply



(b) I/O Waveform

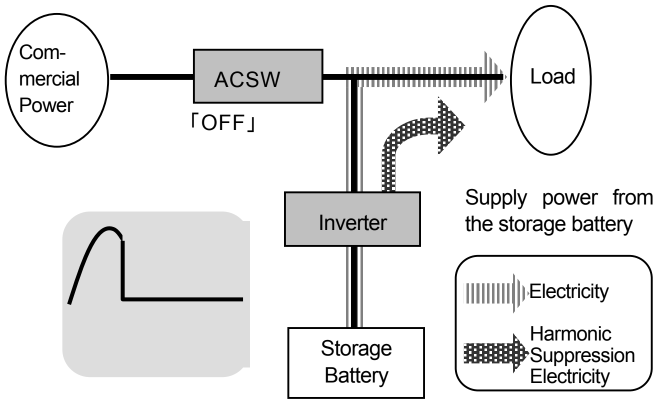


(c) Waveform of when Serge Applied

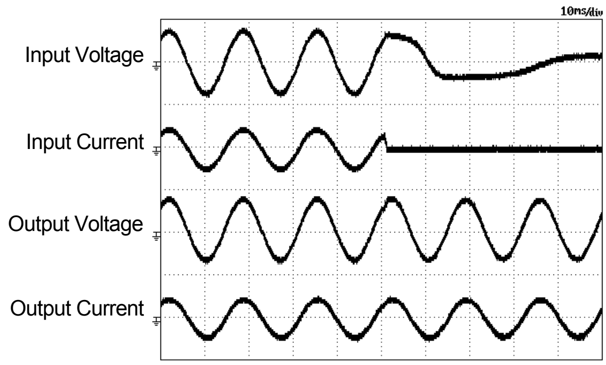
Fig.7 Operation and Waveform of Temporary Supply from Capacitor

If the period of abnormality is short, there is no electrical discharge from the storage battery to turn on ACSW again at once, as shown in Fig. 7(b). Similarly the storage battery is not discharged even if the surge (ring wave) shown in Fig. 7(c) is generated, and the load connected with the output can be protected from the surge.

In addition, if AC input abnormality continues, the power converter operates as an inverter function, and supplies power to the load from the storage battery through the inverter, as shown in Fig. 8(a) and (b).



(a) Status of Power Supply



(b) I/O Waveform

Fig.8 Operation and Waveform of Storage Battery Supply

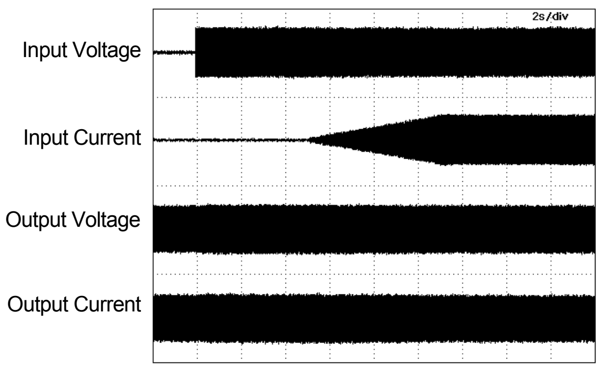


Fig.9 Waveform of After Recovery

(3) After recovery
Fig. 9 shows the waveform when returning from the storage battery operation to normal. As the figure shows, the transient change does not occur with the input current when viewed from the input power supply side, thanks to the walk-in function. This means that there is no need to select a large capacity when there is an engine generator.

4.3 Characteristics of SANUPS E

(1) High efficiency
SANUPS E is highly effective with maximum efficiency of 87% to 97% of the continuous inverter power supply system (comparison using SANYO DENKI products). The reason for this is that the power loss that occurs in the device compared with the continuous inverter power supply system is small.

(2) Momentary power breaks
The commercial power supply and the inverter are always operating in parallel. When abnormalities occur, the commercial power supply can be cut off at high speed and continue supplying power to the load without momentary breakdown. It is also possible to provide protection even when a surge is generated, and at this time, needless storage battery electrical discharge is prevented. (A momentary breakdown of about 2 milliseconds to half cycle is accompanied in the case of the continuous commercial power supply system).

(3) Active filter function
The active filter function controls the harmonic current generated from the load equipment and compensates for the invalid power to control the input current so that the sine wave and the power factor become almost one. Therefore, no harmonic wave problems occur in the input power supply.

(4) For power use
Because the main power during normal use is supplied from the commercial power supply but not from the inverter, the overload capacity has been 800%, 0.5 second, which is superior to that of our conventional models (800%, two cycles). As a result, it is possible to deal even with a major over current, such as a start current on the load side. It is also suitable for the power load.

(5) Small size, high reliability, and economical
The circuit composition is simplified since the power converter consists of one and the number of parts can be lowered. This makes it small and low-cost. Moreover, the mean time between failure (MTBF) extends and the reliability of power supply improves because the number of parts is small.

(6) Storage battery check function
It is advisable to diagnose the storage battery regularly. This UPS is safe because the power supply status does not change when the storage battery is checked. It also has the function that the storage battery can be regularly checked automatically.

(7) Network support
Recent UPS models support network connections. This enables access to functions such as scheduled operation, including auto shutdown at a breakdown, display of the state of operation, and metrics.

SANUPS E has these features, and is ideal as a backup power supply for a power load used for production sites since it is especially effective and has a high over load capacity. A case involving installation in a clean room is introduced as an application example.

4.4 Example Application of SANUPS E in a Clean Room

Because power requirements in a clean room are heavy, a comparatively large UPS is required. Setting a UPS up in the clean room itself is not ideal because the calories generated by a conventional UPS are substantial. Consequently, the UPS is often set up in the power chamber, outside the clean room, but this means that when batch backup is done in the power chamber there is the potential for serious repercussions in the unlikely event that the UPS breaks down. This risk can be attenuated by distributing UPS in a clean room. In the case of a distributed UPS arrangement, the input current of UPS becomes the sine wave and the power factor becomes almost 1, because the UPS has the active filter function. The diameter of long wiring from the receipt terminal to the device can also be reduced.
Since clean rooms demand highly developed temperature and humidity control, heat and the direction of discharge air generated from the UPS are important. With a conventional UPS, the direction of discharge air is from the rear top. This creates problems in a clean room where the current of air is controlled from top to bottom. The direction of discharge air of the heat generated from a parallel processing system UPS can be readly changed and can be discharged from the bottom because the heating value of this UPS is low. Temperature and humidity control can be simplified by discharging heat through grating from the bottom. Fig. 10 shows the parallel processing system UPS with a 100kVA duct that was created for a clean room.
The standard machine has air discharge from the top, but can be from the bottom with a simple duct structure change, since the heat value is small.

Fig. 10 Parallel Processing System UPS with a 100kVA Duct

5. Conclusion

When a UPS was introduced as a backup power supply for equipment in the past, it was usually only the computer that controls the machine tool that was backed up. In addition, many measures were taken with the momentary voltage drop control device for the power load. However, large and midsize UPS have become smaller, lighter and cheaper, and from a cost-effectiveness point of view, it has become viable to limit the damage to power system equipment using UPS that deal not only with voltage drops but also with power failure. This breakthrough is thanks to the emergence of UPS that are more suitable for power load backup. The parallel processing system UPS known as SANUPS E introduced in this paper has features that make it suitable for manufacturing equipment , and I believe this will contribute to the success of our customers' businesses because we are able to propose a system with high cost-effectiveness. Finally, I would like to add that this UPS is a device that can be adapted not only for manufacturing equipment but also for the communications and computer fields. SANYO DENKI will continue to develop backup power supplies that provide even greater customer satisfaction.

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Yoshiaki Okui

Joined company in 1992
Power Systems Div., 1st Design Dept.
Worked on the development and design of The UPS. D.Eng.