Creating One of a Kind Product - Hybrid UPS "SANUPS E23A" for an Energy Saving Era -

Minoru Yanagisawa

1. Introduction

The development of an information society, particularly network advancement, starts with computers and encompasses all forms of information and communication and thus demands that the Uninterruptable Power Supplies (UPS) that provide electricity to all of these devices to be able to provide power reliably through any circumstances. However, as networking has increased drastically in recent years, various types of problems began to occur. For example, network business is dependent on the existence of data centers. As the processing power of the computers used in those data centers increases, so does their electricity consumption. Additionally, as the computers get smaller, more of them can be installed on the same racks, thus increasing the number of computers in the center. The synergy between shrinking computers and increased power consumption causes a drastic increase in the power consumption of each floor and the overall consumption by the data center building. This means that the UPS in the data center must not only be reliable, but also efficient and compact. There are also necessary requirements on a global scale in terms of environmental conservation.

With this in mind, we have sought to keep the reliability offered by current power supplies while increasing efficiency and reducing size and weight. We now introduce the next generation UPS "SANUPS E23A", which will be sold by our company as a hybrid power supply without momentary breaks. The "SANUPS E23A" includes a single power converter to increase efficiency and decrease size while using a new control system to ensure reliability of power, making it the first power supply of its kind. This document introduces control technologies and features of the "SANUPS E23A".

2. Comparison of various types of UPS technology

There are several types of UPS available now. Dividing them by system architecture gives us two types: UPS that have two power converters and use a continuous inverter power supply system and UPS that have a single power converter and use a continuous commercial power supply system. Table 1 is a comparison of these two types of UPS.

Table 1 Comparison of UPS types

Item \ Method	Continuous inverter power supply system UPS	Continuous commercial power supply system UPS
Output power quality	Excellent: Without momentary power breaks	Poor: Power breaks occur
Power loss	Poor: Two converters	Excellent: Uses commercial power
Reliability	Excellent: Continuous operation	Poor: Operation not
Price	Poor: Two converters	Excellent: One converter

The continuous commercial power supply system UPS are smaller and less expensive because they have only one converter. Additionally, supplying power from commercial power suppresses the power loss. However, the output breaks when errors in the power supply, such as power failures, occur before switching to the inverter, thus creating momentary gaps in the power. This limits their use in loaded systems. By comparison, continuous inverter power supply system UPS pass commercial power through two converters, a rectifier and an inverter, thus converting the power from AC to DC and back to AC. This allows for high-quality, sustained power even during errors in the power supply. The drawback is that using two power converters causes a relatively large loss of power. If the problems associated with continuous commercial power supply system UPS could be resolved, we would have a UPS that was reliable, efficient (energy-saving), and low cost.

3. Outline and technologies of a new hybrid UPS without momentary power loss

The "SANUPS E23A" is a new type of UPS (hybrid type UPS without momentary power breaks) that has the merits of both the continuous commercial power supply system UPS and the continuous inverter power supply system UPS mentioned in section 2.

Fig. 1 shows the basic architecture of the "SANUPS E23A". As shown in Fig. 1, the device consists of an ACSW to switch away from commercial power when there is an error in the power supply and there is only a single power converter (inverter).

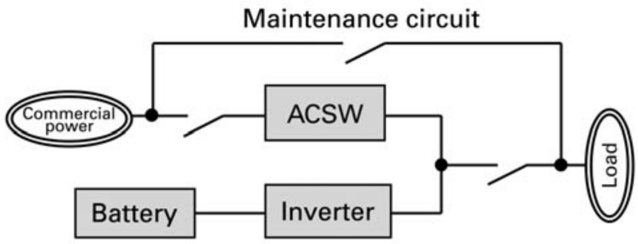

Fig. 1 SANUPS E23A basic architecture

This layout operates with the inverter in line with commercial power that has passed through the ACSW. In this situation, the inverter is outputting the same voltage as commercial power.

Additionally, the inverter can limit its output to only distortion in the load-side current (active filter function) so that only undistorted power in the form of a sine wave is supplied from commercial power. In other words, only useful power is supplied. At the same time, the inverter supplies the battery with regenerative current (charging function). Continuous inverter power supply system UPS pass all usable power through two converters, but this new format does not pass usable power through any converters. This minimizes power loss and supplies efficient power to the load.

Further, because commercial power and inverter power are in parallel redundant operation, the device can cut the flow from commercial power when abnormalities arise and provide battery power through the inverter. Should a problem arise with the inverter, the device can cut the power flow from the inverter and supply only commercial power to the load. This increases the reliability of the UPS. This section introduces the technology that allows commercial power to be cut without a momentary power break in power supply.

Technologies required for power without momentary power breaks

Continuous, stable, uninterrupted power during errors in the power supply, such as power failures, requires the following.

①The inverter must be able to quickly and reliably switch to battery power when a power failure is detected

②It must be possible to quickly cut the power from either the inverter or commercial power

③Abnormalities in AC input must be detected quickly

④Power variations other than power failure and momentary voltage fluctuations must not cause a power loss (battery discharge)

Technologies for ①: Inverter control technologies

Continuous commercial power supply UPS charge the battery from commercial power during normal operation, so the inverter circuit must convert between AC and DC power, as well as to control this conversion and the battery voltage. The current output side becomes the inverter circuit input. It is thus necessary for the DC/AC converter that comprises the battery input to switch between the inverter circuit and its control mechanism when there is a power failure. Thus continuous commercial power supply system UPS must be able to switch the conversion method or the control of the inverter circuit. A small amount of time is then required for the current supply to stabilize, resulting in a break in power supply. Additionally, control after switching uses a control circuit not used during normal operation so there is no compensation from the control unit and reliability is compromised.

"SANUPS E23A" contains a voltage control circuit that controls the uptake of the inverter AC output voltage in the inverter circuit that charges the battery. Fig. 2 shows diagram of the control system. Thus, under normal operation, the inverter circuit converts DC power from the battery to AC power and provides a stable AC output voltage. This allows the DC/AC conversion function of the inverter circuit and the commercial power supply to operate in parallel redundant operation so that problems or failures in commercial power can be compensated for by cutting commercial power and switching to the inverter, which can continue to supply power through DC/AC conversion. Thus the inverter output voltage (UPS device AC output voltage) does not vary and stable a power supply is maintained.

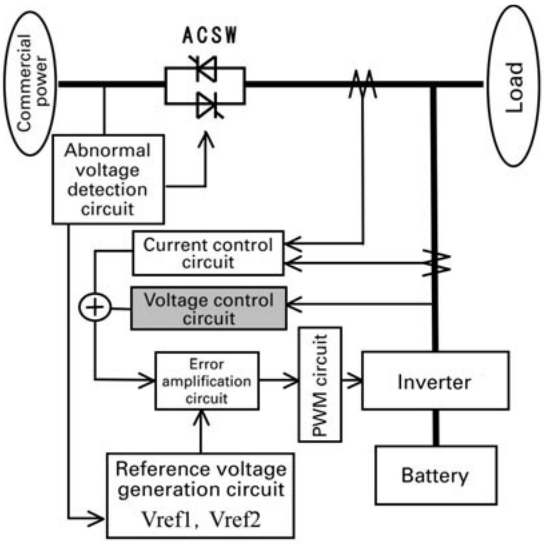

Fig. 2 Control system diagram

Technologies for ②: AC Switch Breaker Technologies

Even when the inverter can supply a continuously stable voltage, an abnormality in commercial power will require a very fast switch between commercial power and the inverter to prevent the abnormality from reaching the load. Normally, devices that will experience a quick break in current include a high-speed circuit breaker or a thyristor with a forced interruption circuit, but both of these options are expensive.

The “SANUPS E23A” uses a thyristor that can handle quick breaks in power for the switch between commercial power and the inverter. The time until the thyristor turns completely off is up to a half cycle of the commercial frequency, so the thyristor may have to be forced off. In general, forcing the thyristor to turn off requires a circuit like the one shown in Fig. 3, which involves major construction, but the “SANUPS E23A” uses a thyristor control technology that allows fast disconnection without this type of circuit.

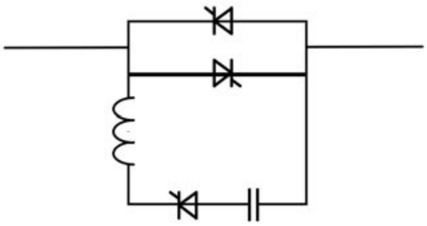

Fig. 3 Thyristor switch with forced interruption circuit

Fig. 2 shows a diagram of the circuit related to the “SANUPS E23A” ACSW-thyristor interrupt circuit. The diagram shows the inverter back-converting the current based on the reference sinusoidal voltage created by the reference voltage generation circuit. One reference voltage for the reference voltage generation circuit is Vref1, which is used via the inverter in equal parts with commercial power when reference sinusoidal voltage is being used. The other is Vref2, which is a high voltage current in phase with Vref1. When commercial power is operating normally, the reference voltage generation circuit will use Vref1 to operate the inverter. If there is an abnormality with commercial power, the abnormal voltage detection circuit will activate, causing the reference voltage generation circuit to switch to Vref2, which is higher than commercial power. This enables a voltage to be output from the inverter as reverse bias against the conduction state of the thyristor and allow the AC switch to break quickly. Fig. 4 displays the interruption of thyristor current.

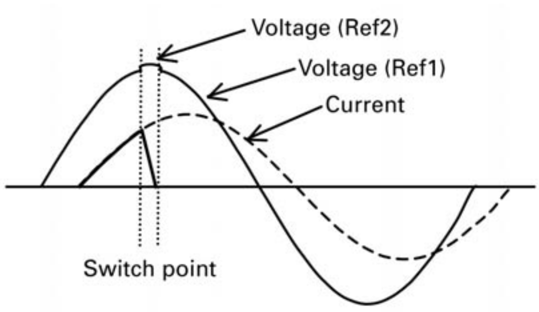

Fig. 4 Interruption of thyristor current

Technologies for ③: Rapid abnormal voltage detection

The abnormal voltage detection circuit displayed in Fig. 2 averages the AC input voltage and matches it with the evaluation circuit to evaluate for an abnormality. When the AC input waveform and the evaluation waveform are in phase and the AC input is the rated voltage, the standard sinusoidal waveform that is equivalent to the amplification level is offset vertically and the detection circuit accepts the band. Abnormality detection in the average waveform is slow, but the effective value of the AC voltage is evaluated accurately. The waveform made of the difference between the band voltage and the AC input is evaluated quickly and the abnormality signal is forwarded to the next circuit. The abnormal voltage detection circuit thus has two levels of detection and detects abnormalities quickly and accurately. Fig. 5 shows the operation of the abnormal voltage detection circuit that used the band voltage.

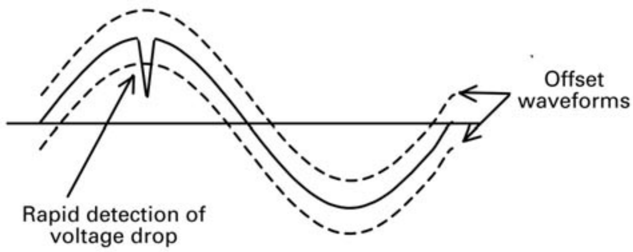

Fig. 5 Abnormal voltage detection circuit operation

Technologies for ④: Preventing battery discharge

The technologies to handle issues ① through ③ are aimed at ensuring a steady supply of power from the UPS should there be a power failure or abnormality with commercial power. However, even if there are no breaks or gaps in output power, power loss due to voltage fluctuations unrelated to loss of commercial power, including power fluctuations that do not need to be covered by energy in the battery or responses to noise in the commercial power, may cause the battery to drain and be unable to supply power should there be an abnormality in commercial power. We have developed the following technologies to prevent unnecessary battery discharge in the “SANUPS E23A”.

Abnormalities in AC input cause the abnormality detection circuit to trigger, turning the ACSW off as shown in Fig. 6 and switching to inverter output without interruption. When this occurs, the electrolytic capacitor in the inverter circuit supplies power to the load. If the abnormality lasts only a short time, the ACSW remains ON and there is no discharge from the battery, as shown in Fig. 7. Additionally, a surge (linkwave) like that shown in Fig. 8 will not cause battery discharge and will neither reach the load nor interrupt power.

Further, if AC input abnormalities continue, the power converter will function as an inverter, as shown in Figs. 9 and 10, and the battery will power the load through the inverter.

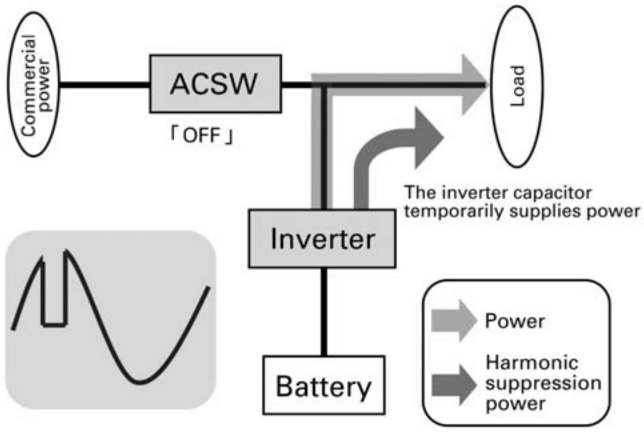

Fig. 6 Power supply via capacitor

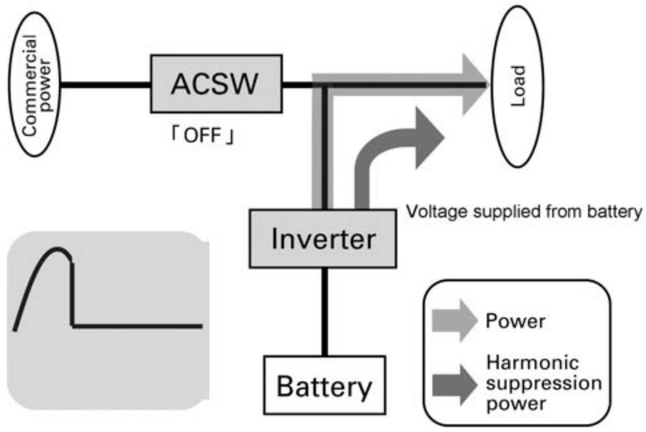

Fig. 9 Power supply via battery

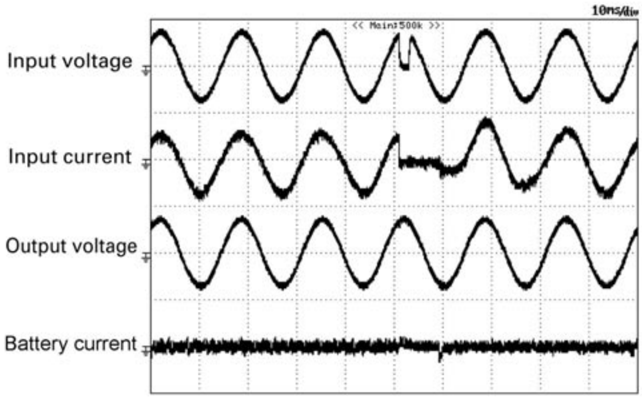

Fig. 7 Waveform for power supply via capacitor

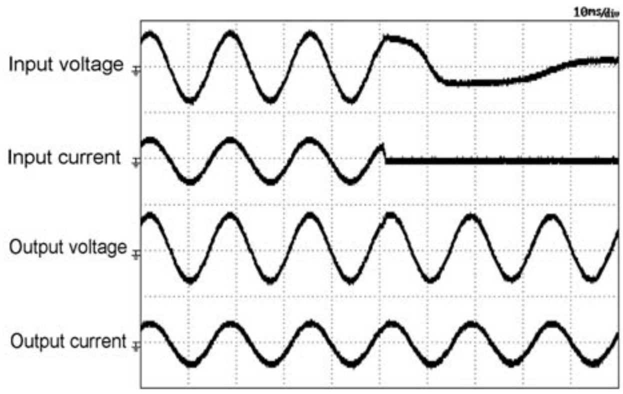

Fig. 10 Battery switching waveform

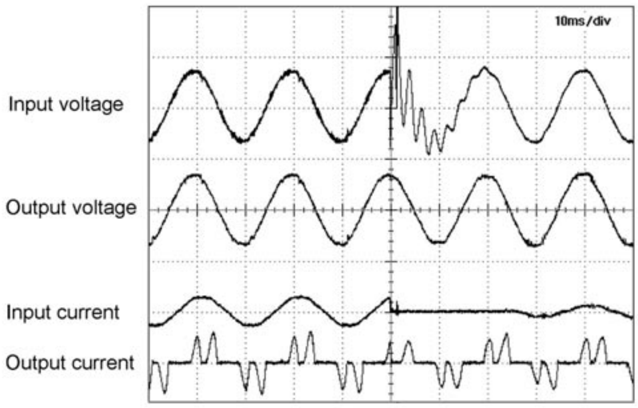

Fig. 8 Waveform with surge applied

4. Characteristics of the "SANUPS E23A" hybrid UPS without momentary power breaks

This section introduces the characteristics of the "SANUPS E23A" hybrid UPS that uses a circuit like that found in a continuous commercial power supply system UPS described above to achieve higher functionality than continuous commercial power supply system UPS. Fig. 11 shows the exterior of a 20 kVA device.

(1) High Efficiency

Compared to a continuous inverter power supply system UPS, the "SANUPS E23A" has a much lower power loss, so the maximum efficiency is raised from 87% to 97% (comparison made with "SANUPS AMA T3" 20 kVA unit).

(2) Without momentary power breaks

Because commercial power and the inverter are on redundant parallel operation, commercial power can be cut very quickly without disrupting power supply to the load if there is an error in the power supply. Additionally, should a surge occur, the load can be protected and unnecessary battery discharge can be prevented. (Continuous commercial power supply system UPS have a break of approximately 2 ms to half a cycle.)

(3) Active filter function

The active filter function suppresses harmonic current generated by the load devices, compensates for ineffective power, controls the input current so that it resembles a sine wave, and controls the power factor so that it is kept as close to one as possible. Therefore, harmonic disturbance is not generated in the input power supply.

(4) Aimed at power applications

Most power during normal operations comes not from the inverter but rather from commercial power, giving an overload capacity of 800% for 0.5 sec. This is a large improvement over our previous model, which had an overload capacity of 800% for 2 cycles. This means that over current caused by events such as powering up the load can be handled easily, so it is, of course, suitable for the operating load.

(5) Small, reliable, and economical

The “SANUPS E23A” uses only one power converter, which simplifies circuit construction and reduces the part count. This results in a smaller, less expensive device. Additionally, the lower part count increases the mean time between failures (MTBF), which increases the reliability of the power supply.

(6) Battery check functions

Periodic checks of the battery are desirable. This UPS is stable as it does not interrupt the power supply to check the battery, and it has a function that automatically checks the battery periodically.

(7) Network compatibility

The “SANUPS E23A” is network compatible and can make use of functions such as automatic shut down during a power failure, scheduled operating, and operating state/measurement value display.

Fig. 11 External view of the “SANUPS E23A”

5. Conclusion

The need for continuous and reliable power supplies is growing not just with computers, but with all types of equipment. The “SANUPS E23A” hybrid type UPS introduced in this document provides uninterrupted power with high reliability and low loss through its unique architecture, resulting in an excellent tool for our customers' energy saving needs. We believe that environmentally gentle equipment such as this is an excellent step towards preserving our environment.

We shall continue to strive for higher reliability and better efficiency and to provide world-leading products.

Minoru Yanagisawa
Joined Sanyo Denki in 1980.
Power Systems Division, 1st Design Dept.
Worked on the development and design of power supplies.