Development of the Mid-capacity UPS "SANUPS E23A-Li" with Lithium Ion Battery

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1. Introduction

As networking advances, uninterruptible power systems (UPS) are applied to various IT and communications devices, such as computers. At the same time, industrial improvements and secrecy related to manufacturing equipment increase the risk of reductions in production yield due to irregularities in the power supply, making backups during those irregularities a greater priority. When evaluating measures to protect against irregularities in the power supply, cost effectiveness, and size become key factors. For this reason, Voltage Sag Compensation is applied to manufacturing equipment. However, Voltage Sag Compensation can only protect against less than a full second of power irregularity. It cannot provide backup protection for any longer than that. Additionally, stopping a production line for maintenance of manufacturing equipment can be difficult, so there is a rising demand for equipment with a long lifespan. Finally, the recent growth of the environmental movement has created a demand for products with something other than the environmentally-damaging lead-acid batteries that have been the standard in the industry.

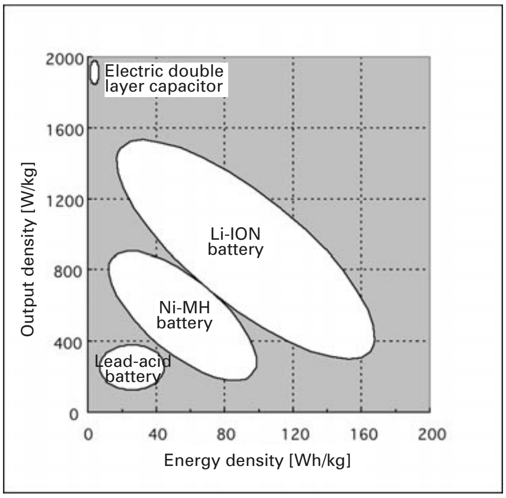
We have developed the "SANUPS E23A-Li" UPS to use an environmentally-friendly lithium ion battery as well as to be small and lightweight and able to protect against both voltage drops and voltage loss. This document outlines the basic architecture and features of the "SANUPS E23A-Li."

2. Development Background

At the present time, power quality in Japan is consistently world class. However, natural disasters that stop the flow of power are unavoidable. Should power lines be damaged, safety would require any electric power systems to be switched to a different source of power immediately. In the event of an accident, the voltage at the site of the accident can drop for anywhere from 0.07 to 0.3 seconds (voltage sag). Moreover, power may not be restored until a minute or two after the damage to the system has been repaired (brief blackout)(1).

A production line subjected to voltage sag or brief blackout can suffer serious damage. This has traditionally been prevented with a protective device that utilizes a capacitor on the battery. However, it is possible that a capacitor will provide protection for less than a full second and thus only be useful for voltage sag, offering no protection in the case of a brief blackout or power failure. Because UPS units use lead batteries, installing a UPS on the production line takes up extra space and increases maintenance costs because of regular inspections and battery changes. Also, because variations in current due to load can be very large on a production line, a backup power supply with a high overload capacity must be used.

With this as our motivation, we looked to the "SANUPS E23A"(2) high efficiency, high overload capacity parallel processing UPS (referred to as a "Hybrid UPS" at Sanyo) for heavy industry as our guide. We now propose a UPS that can protect against not only voltage sag, but also brief blackout and power failure.



Energy density: the amount of electrical power the unit can produce in one hour
Output density: The maximum instantaneous electrical output

Figure 1 Comparison of energy density and output density for different battery types.

Comparing parallel processing UPS systems and equipment that protects against voltage sag shows that the circuits are quite similar but that the batteries differ in backup time(3). Electric double layer capacitors are often employed for backing up only in voltage sag, as is the case with most voltage sag protection devices. UPS units generally use lead-acid batteries and provide a backup time of 5 minutes or more. In order to provide backup for brief blackout, a storage element with a higher energy density is more suitable than an electric double layer capacitor or a lead-acid battery, so as a storage element, nickel hydride batteries and lithium ion batteries both met this description. Figure 1 shows the relationship between energy density and output density for each type of battery.

As shown in figure 1, lithium ion batteries have four to six times the energy density of lead-acid batteries and three to four times the output density. Lithium ion batteries also have twice the output density of nickel hydride batteries. On the other hand, when compared to the electric double layer capacitor, the lithium ion battery has a much lower output density but had a 30 to 50 times higher energy density. For one to two minutes of backup power, the high energy density of the lithium ion battery is the best choice. In addition to their small size and low weight, lithium ion batteries have a high discharge rate so a small battery can deliver a great deal of energy in a very short period of time. It is thus ideal to use lithium ion batteries ideal for backups during voltage sag.

With all of the above in mind, we set out to create a version of the industrial UPS "SANUPS E23A" that incorporates a lithium ion battery. This is how the small, light weight, long-life "SANUPS E23A-Li" UPS was born.

3.Circuit Architecture of the "SANUPS E23A-Li"

3.1 Basic Architecture

The basic architecture of the "SANUPS E23A-Li" is shown in figure 3.

As shown in figure 3, the "SANUPS E23A-Li" is comprised of an inverter board and a battery board.

The inverter board uses the parallel processing unit from the "SANUPS E23A" UPS and, as shown in figure 3, connects it in parallel with a power converter and commercial power. Normally, commercial power is fed directly to the load while the power converter controls any harmonics that arise from the load when operating in active filter mode. The charger charges the battery at the same time that all of this is happening (parallel processing). The type of power supplied to the load is determined by the UPS as it looks at the power from the commercial power and the quality from the inverter. During normal operation, only the "quality" component is handled by the inverter. Compared with consistent inverter supply, this method has less power loss and can thus supply power to the load more efficiently. If there is a problem with the commercial power supply, the device immediately switches off of the commercial power supply and the power converter begins to

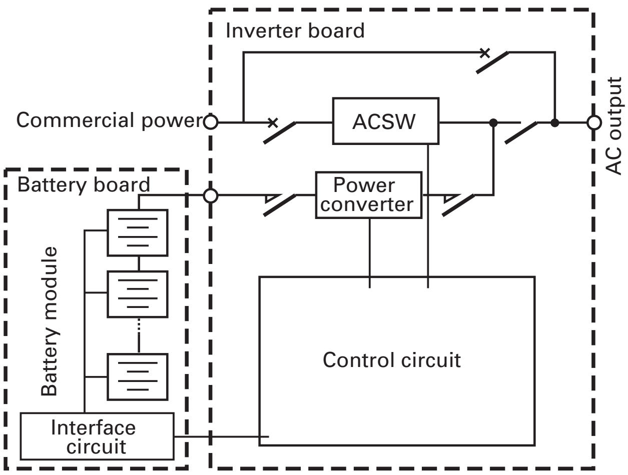


Figure 3 Basic layout of "SANUPS E23A-Li"

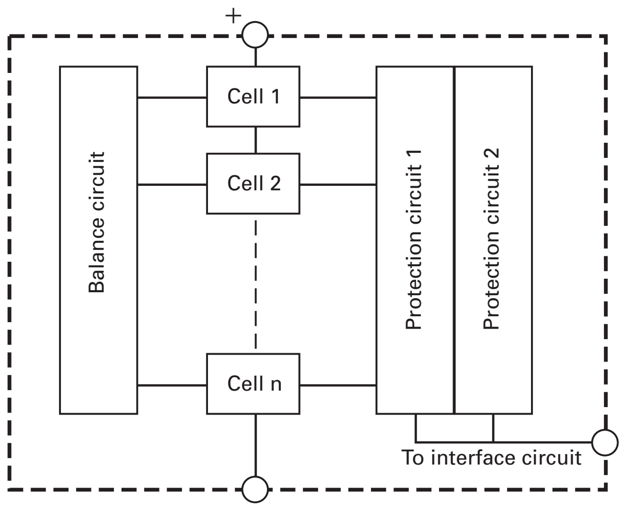


Figure 4 Basic layout of battery module

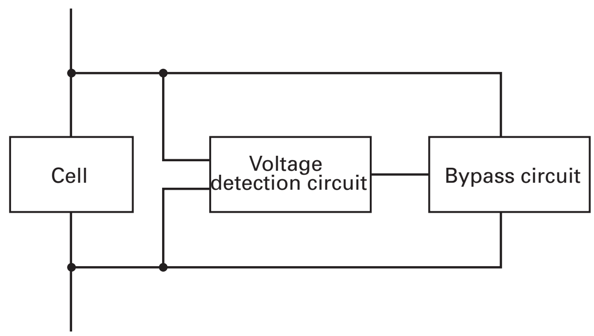


Figure 5.1 Bypass system

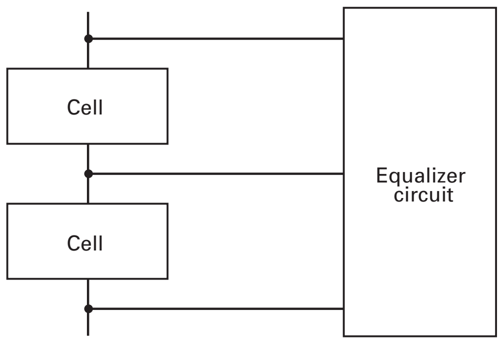


Figure 5.2 Equalizer system

supply power to the load through the inverter. This happens quickly enough that there is no effective interruption in the power supply, making this a very reliable UPS.

The battery board is comprised of an interface circuit and a battery module from Nagano Japan Radio Co., Ltd. A basic diagram of the battery module is shown in figure 4. As shown in figure 4, the battery module is comprised of a lithium ion battery, a balance circuit, and two protection circuits. Connecting this to the UPS requires low voltage and a serial connection. The cell may generate voltage variations due to differences in self-discharge, so a small cell will have its lifespan shortened by overcharging or over discharging. The balance circuit is required to prevent this from happening.

The major components of the cell voltage balance circuit are shown in figures 5.1 and 5.2.

The bypass system causes the charging current to bypass any cell for which the voltage detected by the voltage detection circuit

Table 1 Standard specifications for the "SANUPS E23A-Li"

Item type / Name			E23AL203	E23AL503	E23AL104	E23AL204	Remarks
Rated output capacity (apparent power / active power)			20kVA / 16kW	50kVA / 40kW	100kVA / 80kW	200kVA / 160kW	
Format	Operating system		Parallel processing				
Format	Cooling system		Forced air cooling				
AC Input	Phases / Lines		Three phases, three lines				
AC Input	Rated voltage		200V(205,210V)				
AC Input	Rated frequency		50 or 60 Hz				
AC Input	Required capacity		20.0 kVA or less	51.3 kVA or less	102.6 kVA or less	205.2 kVA or less	
AC Input	Power factor		0.98 or greater				Under standard conditions
AC Input	Compensation of distorted current	Compensation capacitance	Within rated capacity				
AC Input	Compensation of distorted current	Degree of compensations	2nd to 20th harmonic				
AC Input	Compensation of distorted current	Compensation ratio	85% or less				At full wave rectifier load
AC Output	Phases / Lines		Three phases, three lines				
AC Output	Rated voltage		200V(205,210V)				Same as for AC input
AC Output	Voltage precision	When using commercial power	Between –8% and +10% (on output)				Voltage precision can be adjusted
AC Output	Voltage precision	When using the battery	Within ±2% of the rated voltage				
AC Output	Rated frequency		50 or 60 Hz				The same as for AC input
AC Output	Frequency precision	When using commercial power	Within ±4% of rated frequency (on output)				Frequency precision can be changed
AC Output	Frequency precision	When using the battery	Within ±0.1% of the rated frequency				
AC Output	Load power	Rated	0.8 (slow)				
AC Output	Load power	Fluctuation range	0.7 to 1.0 (slow)				
AC Output	Voltage waveform distortion factor	With a linear load	2% or less				
AC Output	Voltage waveform distortion factor	When using the battery	5% or less when using the wave rectifier load				
AC Output	Voltage unbalance ratio	When using the battery	2% or less				One third of total capacitance is put into one line
AC Output	Instantaneous voltage variation	Rate of variation	±5%				When using battery power
AC Output	Instantaneous voltage variation	Transient response time	50 ms or less				
AC Output	Overload capacity	When using commercial power	200% (30 seconds), 800% (0.5 seconds)				
AC Output	Overload capacity	When using the battery	150% (1 minute)				
AC Output	Time to switch to battery operation		Without momentary power breaks				
Battery		Type	Lithium ion battery				
Battery		Backup time	2 minutes				
Battery		Nominal voltage	353V				
Efficiency (AC-AC)			97% or more				
Noise			57 dB or less	65 dB or less		70 dB or less	1 min front of and 1 m above the device
Interface			LAN interface card (optional)				
Operation environment			Operating ambient temperature: 0 to 40°C, Ambient humidity: 30 to 90% (No condensation)				

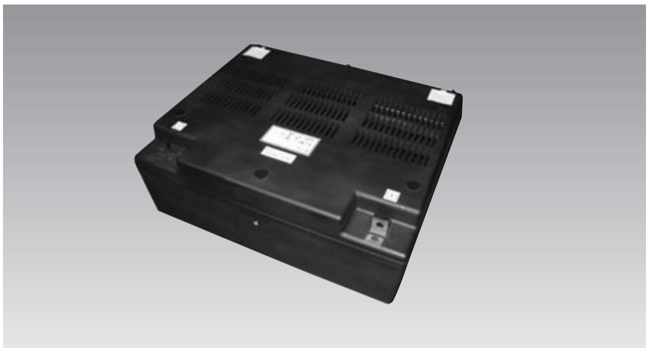


Figure 6 Exterior view of the lithium ion battery module (Nagano Japan Radio Co., Ltd.)

Figure 7 Exterior view of the "SANUPS E23A-Li"

is greater than the set value (figure 5.1). The equalizer system transfers charge from the cell with the highest electrical potential to the cell with the lowest to balance out the charge across the cells (Figure 5.2). This development cycle has made it possible to charge all cells to any level desired and has improved the accuracy of the equalization function and thus lengthened battery life by adding the equalizer circuit.

Additionally, protection against heating of the battery or weakening of the battery due to overcharging caused by damage to the balance circuit and protection against over discharging are integrated into the circuit.

Protection circuit 1 monitors cell voltage and stops charging if any irregularities arise. Additionally, the inverter board has a protection circuit that detects abnormalities in the voltage of the charging battery and thus provides a second layer of protection, creating a very safe system.

Protection circuit 2 monitors the temperature of the cell for abnormalities. There are two levels of temperature sensing, creating much greater safety. The first step in temperature detection activates the cooling fan if any abnormalities are detected. The second step shuts off the charging function when abnormalities are detected.

An exterior view of the lithium ion battery module is shown in figure 6.

3.2 Specifications

The specifications for the "SANUPS E23A-Li" are shown in table 1. Figure 7 shows an exterior view of the unit.

4. Features of the "SANUP E23A-Li"

4.1 Built-in lithium ion battery

(1) Safety

The lithium ion battery used in this development cycle is a manganese lithium ion battery. Manganese lithium ion batteries have a lower charge capacity than cobalt lithium ion batteries but suffer less degradation and lower risk of fire from overcharging or over discharging. This makes them significantly safer.

(2) Long life

Power supplies for industrial use require a long life span to reduce maintenance. Lithium ion batteries have a much greater charge and discharge lifespan than do lead-acid batteries. The "SANUPS E23A" was designed for maximum battery usage efficiency. The monitoring of cell voltage and temperature also help to increase the lifespan of the battery.

4.2 Light weight

Use of an optimized lithium ion battery instead of a lead-acid battery in this development cycle helped us reduce the weight of the battery by 70%. However, because increased safety and longer life were our primary concerns, the overall size of the unit remains roughly the same as the lead-acid battery model.

4.3 High efficiency

Because this UPS uses the inverter from the "SANUPS E23A" UPS, waste due to power loss in the interior of the unit is very low, with efficiency reaching 97%.

4.4 No momentary power breaks

With the commercial power supply and the inverter operating in parallel, any irregularities in the commercial power supply cause the commercial power supply to be cut off very quickly and the load transferred without any momentary power breaks. If the problems with the commercial power supply only last a short time or are due to a power surge, the electrolytic capacitor in the inverter can supply power to the load. In such a case, there is no discharge from the lithium ion battery and unnecessary discharge is prevented, thus increasing the lifespan of the battery.

4.5 Active filter function

The active filter function controls harmonic currents generated by load devices, protects against ineffective power, and ensures that the power factor of the input sine wave and power factor stay very close to one. All of these functions prevent damage from harmonics in the input power supply.

4.6 Designed for power applications

Most of the power supplied during normal operation comes from the commercial power supply rather than the inverter. This creates a very high overload capacity (800% for 0.5 seconds). This means that high currents such as the start current are easily handled and that the drive load can be handled.

4.7 Network compatible

Use of the optional LAN interface card allows you to use our "SANGUARD" UPS management software to handle automatic shutdown in the case of power stoppages, as well as offering other useful and convenient maintenance functions such as operation schedules, operating conditions, and display of measurement values.

5. Conclusion

This document has introduced the "SANUPS E23A-Li" mid-capacity UPS with built-in lithium ion battery that we have developed. Our next goal is to improve the quality of the lithium ion battery and reduce the size and weight of the overall unit while increasing the length of the backup time.

We have received a great deal of support from Nagano Japan Radio Co., Ltd. in the design, development and production of this product. We would like to thank them, as well as the many other people from whom we have received guidance and cooperation.

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