Development of the High Performance Voltage Dip Compensator "SANUPS C23A"

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1. Introduction

The "SANUPS E" series [1] uninterruptible power supply system (referred to below as "UPS") with parallel processing system is continuing expand the market into the production equipment field (power loads, and so forth), for which it was not previously suited.

However, as maintainability, cost-benefit performance and space-saving are considered important in the production equipment field, voltage dip compensators (dip compensators) are often installed.

Thus, starting with the basic "SANUPS E23A", we combined it with an electric double layer capacitor to create the voltage dip compensator "SANUPS C23A" with a short-time rating specification. This document describes the features of the "SANUPS C23A" .

2. Background

In recent years, as production systems have become more complex and advanced, instantaneous voltage dips (referred to below as "dips") have occurred over a wider range. There are many cases in which factories manufacturing products such as semiconductors and liquid crystals suffer damage from dips. Products and equipment are sometimes damaged during production or transportation by emergency shutdown caused by dips. It sometimes requires enormous effort to restart machinery that has shut down.

The main cause of dips is lightning strike. When lightening strikes power lines, voltage dips centered in the strike point [2]. This voltage dip lasts 0.07 to 0.3 seconds [3] until the protective relay starts to work. As a result, power supply is stopped in some areas due to the disconnection of the strike point, and the power source is lost for a short time until it is reconnected and the grid is switched over. This is an instantaneous power outage (referred to below as "instant outage").

Improvement and modernization in Japan's electric power condition have greatly reduced the incidence of power outage, but accidents due to lightning strikes cannot be completely avoided. Therefore, it is still important to take actions for dips and instant outage. A private advisory panel of the Director-General of the Agency for Natural Resources and Energy has also reported in the council for infrastructure reinforcement of electric power usage that dips are physically unavoidable and it will be reasonable to take actions at load equipment or at consumer side [4]. This further emphasizes that it is necessary for consumers to take actions for dips and instant outage.

There are many cases in which the dip compensator or UPS is installed in the production system as a measure for dips and instant outage at consumer side.

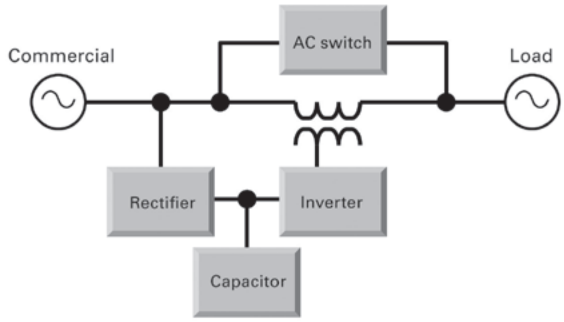
Fig.1 shows an example of a dip compensator.

As a series compensating system (a) and trans-tap switching system (b) control voltage variation in the commercial power source, they compensate only dips. Also, as the power source cannot be released when there is an instant outage or power outage, it is considered they affect safe stop of power equipment and its sequential input after the recovery.

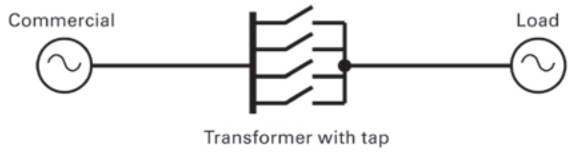
A standby system (c) compensates both dips and instant outage, and the power source is released, thus this system is able to handle with safe stop and sequential input of power load when there is an instant outage or power outage.

However, none of these systems prevent instantaneous interruptions completely, having minimum power breaks of 2msec when switching.

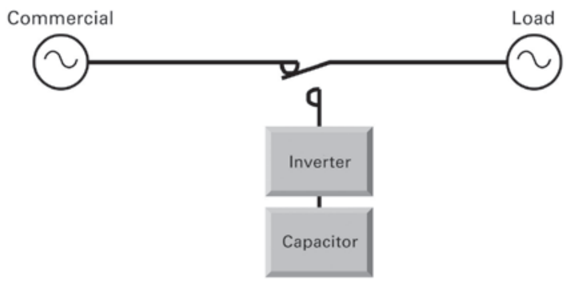
Fig.2 shows an example of a UPS. As shown in the figure, UPS is divided into online type and standby system.



(a) Series compensating system

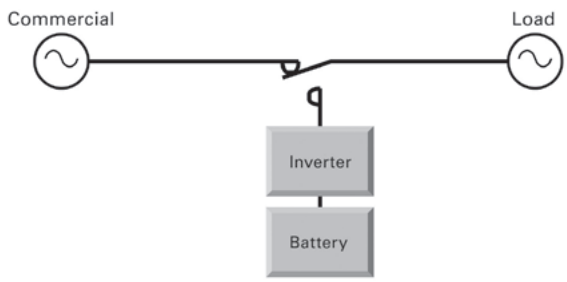


(b) Trans-tap switching system

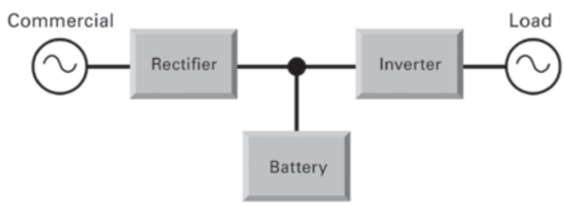


(c) Standby system

Fig. 1: Example of a dip compensator



(a) Standby system



(b) Online type

Fig. 2: Example of a UPS

A standby system (a) has the same configuration as the dip compensator except for the battery. There is a type in which a flywheel is used instead of the battery. As this system has only one power converter, it allows for small size and low cost, keeping the power loss low during normal operation. However, when there is a problem with the commercial power source, this system may have an instantaneous interruption.

In an online type (b), as the inverter always supplies the power to the load, UPS supplies high-quality power without interruption even when there is a problem with the commercial power source. However, as two power converters are required in this type, the power loss during normal operation is high.

Table 1 compares the dip compensator with UPS.

Table 1: Comparison

	Voltage dip compensator			UPS	
	Series compensating system	Standby system	Trans-tap switching system	Standby system	Online type
Dip	Yes	Yes	Yes	Yes	Yes
Instant outage	No	Yes	No	Yes	Yes
Without interruption	Partial	Partial	Partial	Partial	Yes
Operating efficiency	Yes	Yes	Yes	Yes	No
Weight	Yes	Yes	No	No	No
Lifetime	Yes	Yes	Partial	No	No
Power load	Yes	Yes	Yes	Yes	No

As the dip compensator shown in Fig.1 does not prevent instantaneous interruptions completely, it needs to match with dip tolerated dose of the load equipment, and the online type UPS shown in Fig.2 supplies power without interruption, but its operation is inefficient and it is not suited for the production equipment such as power loads. Also, as the UPS mainly uses lead storage batteries, its lifetime is short and maintenance is required.

Also, except for dips and instant outage, with the advancement and speed-up in the production equipment field, excessive consumption power (peak current) generated when power equipment such as motors starts up and regenerative electric power generated when it stops have been increased. The flicker and voltage rise in the commercial power source at that time may lead to functional loss of other devices and stop the devices. Until now, the main measures for peak current have been a reselection of power receiving equipment and capacity increase of wiring, but these measures require extra construction costs. On the other hand, equipment (the large-capacity capacitor and resistor) to release the extra power should be added for regenerative electrical power, therefore huge equipment investment is required.

We therefore developed the high-performance and all-in-one voltage dip compensator "SANUPS C23A" by combining the "SANUPS E23A", which can supply power to the power loads like the standby system and is parallel processing system with no interruption, with the electric double layer capacitor as a short-time rating specification. It realized a long-life and maintenance-free. And also, since peak current and regenerative electric power are absorbed at the power source devices, there is no need to review the equipment.

3. Overview of the "SANUPS C23A"

3.1 Basic configuration

Fig.3 shows the basic circuit configuration of this product.

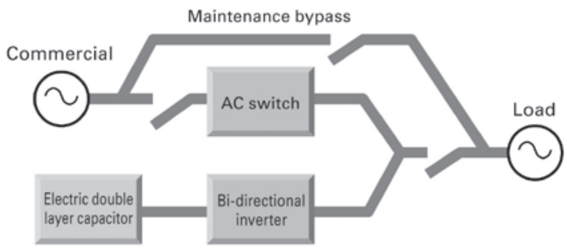


Fig.3: Basic circuit configuration of the "SANUPS C23A"

The "SANUPS C23A" uses a parallel processing system, and the electric double layer capacitor is used for the storage element.

The parallel processing is the same system as the "SANUPS E" series [1], in which the inverter is connected parallel to the commercial power and the main power is supplied through the AC switch-only circuit. This time, the inverter controls as if it operates with the commercial power source with parallel redundant, and at the same time, the inverter performs the active filter function, which controls harmonic current, and charging function to the capacitor. This means that "the power is supplied by the commercial power source and quality by the inverter", and only "quality" is supplied via inverter during normal operation. Thus, power loss is significantly reduced and the power is supplied with high-efficiency and high quality.

Also, when there is a problem with the commercial power source, it is immediately disconnected and the inverter continues to feed. This is the high reliable system which can supply power to the load without interruption.

An electric double layer capacitor is used for the storage element. It has a higher output density than lead storage batteries and lithium ion batteries and is suitable for backup for a few seconds such as in the dip. This electric double layer capacitor is basically the same as an electrolytic capacitor and long life design is available because lifetime conversion in the use environment and use rate is possible. Also, as the electric double layer capacitor does not contain harmful chemicals such as lead, it can be handled with as general waste with minimal environmental effects.

3.2 Specifications

Table 2 shows the general specifications for the "SANUPS C23A", and Fig.4 shows an image of 200 kVA of rated capacity.

Fig. 4: Image of the "SANUPS C23A" (200 kVA)

4. Features of the "SANUPS C23A"

4.1 Small size and space-saving

Compared to the "SANUPS E23A" (200 kVA) containing a lead storage battery, both volume ratio and installation area ratio have been reduced to approximately 50%.

4.2 Low running cost

"SANUPS C23A" reduces steady power loss compared to the online type, thanks to high-efficiency. Also, it does not require the periodic part replacement by using the dual electric layer capacitor and long-life fan. Thus, the cost for power loss and maintenance can be reduced at the same time.

Table 2: General specifications

Item			C23A103	C23A203	C23A303	C23A503	C23A104	C23A204	Remarks
Rated capacity			10 kVA	20 kVA	30 kVA	50 kVA	100 kVA	200 kVA	
Rated output			8 kW	16 kW	24 kW	40 kW	80 kW	160 kW	
Board structure			Steel-sheet independent board closure type (International protection code IP2X)						
Operation method			Parallel processing method						Online type
Cooling method			Forced air cooling						
Storage element			Electric double layer capacitor						
AC input	No. of phases / wires		3-phase, 3-wire						
AC input	Rated voltage		210 V (200 V, 220 V)						
AC input	Rated frequency		50 or 60 Hz						
AC input	Distorted current compensation	Compensation capacity	Within rated capacity						
AC input	Distorted current compensation	Harmonic current	85% or more of compensation rate						At 100% rectifier load
AC input	Distorted current compensation	Degree of compensation	2nd to 20th harmonic						
AC input	Input power factor		0.98 or more						During rated operations
AC output	No. of phases / wires		3-phase, 3-wire						
AC output	Rated voltage		210 V (200 V, 220 V)						Same as AC input
AC output	Voltage precision	Commercial power	Within -8 or +10% of rated voltage						Adjustable in settings
AC output	Voltage precision	Capacitor	Within ±2% of rated voltage						Note 1
AC output	Rated frequency		50 or 60 Hz						
AC output	Frequency precision	Commercial power	Within ±4% of rated frequency						
AC output	Frequency precision	Capacitor	Within ±0.1% of rated frequency						Note 1
AC output	Load power factor	Rated	0.8 (slow)						
AC output	Load power factor	Fluctuation range	0.7 to 1.0 (slow)						Note 2
AC output	Voltage waveform distortion (when using capacitor)	Linear load	2% or less						
AC output	Voltage waveform distortion (when using capacitor)	Wave rectifier load	5% or less						
AC output	Voltage imbalance (when using capacitor)		Within 2%						With load of 1/3 total capacitance on one line
AC output	Transient voltage variation (when using capacitor)	Fluctuation rate	Within ±5%						
AC output	Transient voltage variation (when using capacitor)	Settling time	Up to 50 ms						
AC output	Overload capacity (direct feed circuit)		200% - 30 seconds; 800% - 0.5 seconds						
AC output	Overcurrent protection		Inverter halts at 110% of rated current, and power comes directly from mains. Falling to rated current or below automatically starts the inverter for normal operation.						
AC output	Output regeneration power handling	Maximum regeneration power	50% or less						Shifted to device rating
AC output	Output regeneration power handling	Maximum regeneration power volume	10 kW	20 kW	30 kW	50 kW	100 kW	200 kW	
AC output	Switching time for capacitor charging		0 seconds (no interruption)						
AC output	Dip compensation time		1 second or more (at rated load)						Note 3
AC output	Initial charging time		Up to 240 seconds	Up to 180 seconds	Up to 60 seconds				Capacitor voltage from 0 to 100%
AC output	Recharging time		Less than 10 seconds						After compensating for a 1 second voltage dip
Noise			Up to 59 dB		Up to 65 dB				A characteristics
Environment			Operating temperature: 0 to 40°C; Relative temperature: 30 to 90% (no condensation)						

4.3 High performance

(1) Without any interruption

“SANUPS C23A” controls so that a commercial power source and the inverter always operate in parallel redundant [5], and when there is a problem with the commercial power source, it disconnects the commercial power with high speed by means of AC switch in our own method [6] and supplies power without interruption as shown in Fig.5. Also, “SANUPS C23A” minimizes synchronization input time after the recovery, and returns to parallel feeding immediately after inputting AC switch since, for the inverter output, the output voltage and frequency which are present immediately before the commercial power problem are maintained even when the power is recovered. Minimizing the synchronization input time reduces the capacity of the electric double layer capacitor which is required for other than instant outage compensation time and allows for optimal volume selection.

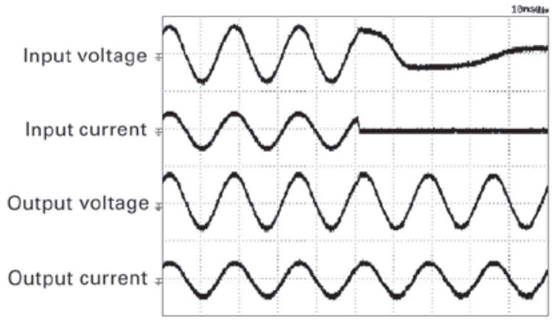
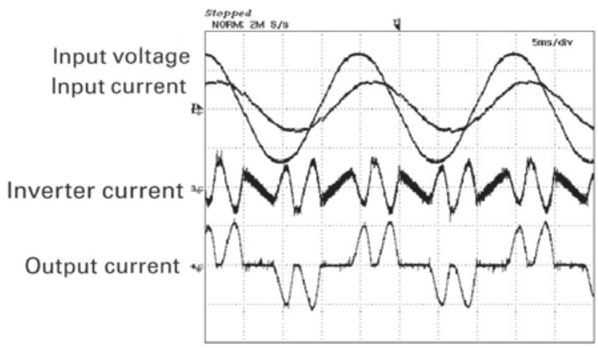


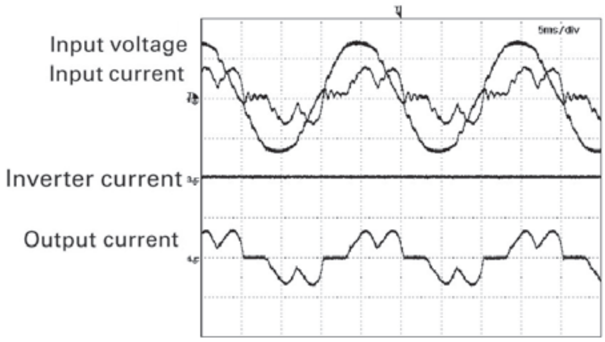
Fig. 5: Uninterrupted waveform

(2) Active filter function

The active filter function inhibits harmonic current generated by the load equipment, compensates for reactive power, and controls the input current to be sine wave and the power factor to be 1. Fig.6 (a) shows the input-output waveform with the active filter function and Fig.6 (b) shows that without the active filter function. This shows that the input voltage (commercial power source) is distorted if there is no active filter function. The active filter function thus prevents harmonic disturbance in the commercial power.



(a) Waveform with active filter



(b) Waveform without active filter

Fig. 6: Effects of the active filter

(3) Peak cut function

By complementing the load power that exceeds the setting power of the peak cut against the peak power of the load equipment, from the electric double layer capacitor, the commercial power can be leveled. Fig.7 shows an example of the power pattern when the peak cut function is working. The load power that exceeds the peak cut setting is discharged from the electric double layer capacitor, and then the discharged load power is charged. This means the commercial power is leveled to below the peak cut setting.

The power leveling by the peak cut function controls flicker from the commercial power source and reduces the costs for power receiving equipment.

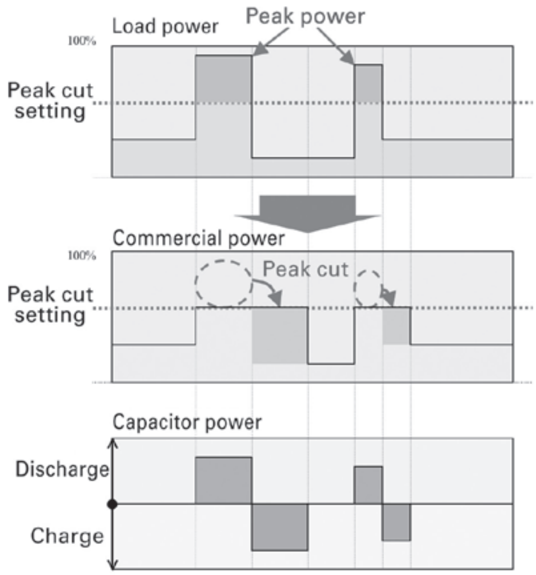


Fig. 7: Power pattern during peak cut operation

(4) Usage of regenerative electric power

Regenerative electric power generated by power loads, and so forth is charged to the electric double layer capacitor, without going back to the commercial power source, allowing the regenerative electric power to be used in the load equipment. Fig. 8 shows an example of the power pattern when regenerative electric power is generated. Regenerative electric power generated by the load equipment is charged to the electric double layer capacitor and then discharged to the load equipment. As the regenerative electric power is not returned to the commercial power source, equipment such as the large-capacity capacitor and resistor is not necessary.

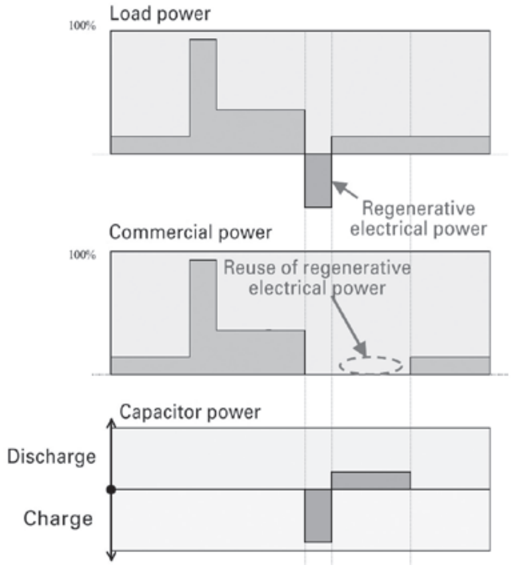


Fig. 8: Power pattern when regenerative electric power is generated

4.4 High reliability

Feeding performance test from the electric double layer capacitor is carried out automatically regularly while power is being supplied by the commercial power source, thus the device can operate reliably when actually there is a dip. When the electric double layer capacitor wears out, an alarm is on while feeding to indicate it needs to be replaced.

5. Conclusion

This document described the all-in-one high-performance voltage dip compensator “SANUPS C23A” containing the electric double layer capacitor.

Our next step is to develop specialized power devices for each function to meet customer needs and enrich systems; develop the dip compensator for 400V large capacity UPS “SANUPS E33A” and specialized peak cut devices.

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