Development of the High Performance Voltage Dip Compensator "SANUPS C33A"

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1. Introduction

We developed the instantaneous voltage dip compensator "SANUPS C33A" for 400 V systems using the parallel processing method (hereafter known as the voltage dip compensator). With the development of the "SANUPS C33A" model, we developed the first voltage dip compensator in the industry to realize completely individual parallel operation control and achieve high reliability while attempting to strengthen our mid capacity lineup. Furthermore, a function that allows the device to reuse regenerative electric power actively works for energy conservation. In addition, the model has a peak-cut function that can suppress flicker, thus reducing equipment costs. In other words, while the conventional voltage dip compensator was a device to combat instantaneous voltage dip, the "SANUPS C33A" makes efforts towards improving power quality, including measures for voltage dip and energy conservation, making it the best high performance power supply device for factories with many equipment with motors.

We developed a lineup with a 150 kVA basic unit and a 300 kVA unit. This document introduces the features of the "SANUPS C33A".

2. Background of the Development

In recent years, measures against instantaneous voltage dip (hereafter known as voltage dip) have advanced in the manufacturing industry, centering around semiconductor manufacturers, and many manufacturers have planned the introduction of voltage dip compensators. In the past several years, a trend has developed where manufacturers introduce large capacity voltage dip compensators to back up several MW class systems at once for high voltage at the factory terminal. While systems that back up everything at once are easy to manage, the initial introduction costs are high and the system is highly affected during a breakdown. With this in mind, many requests appeared for a dispersion system that arranged devices in just the right place for low voltage. With a dispersion system, devices are placed only in the locations that need backup, so this method is very effective for reducing costs. Furthermore, devices can be introduced systematically, so the initial costs can be equalized and decreased.

The manufacturing industry is also improving efforts towards energy conservation in order to combat the issue of global warming. Manufacturing equipment uses many motors, but there was a problem where the regenerative electric power created during deceleration was often consumed by regeneration resistance. When a large amount of torque was generated instantaneously while powering, a voltage dip phenomenon known as "flicker" would occur if the power distribution path was fragile, thus inviting decreased power quality during various situations in addition to voltage dip on the power distribution systems from the power company. In addition, there were problems such as power quality decreasing due to distortion cause by power distribution voltage from harmonic current from the diode rectifier.

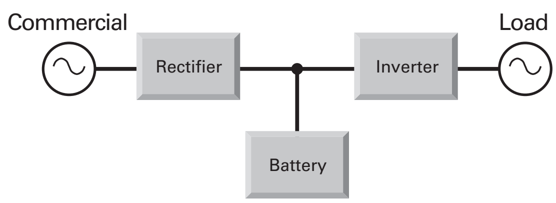
We pushed forward with development of the "SANUPS C33A" as a device to combat these power quality problems and provide energy saving for factories. The base model was the "SANUPS E33A", a high efficiency parallel processing type UPS developed in 2002. This model has a enough of a track record with uninterrupted power supply characteristics and active filter characteristics to suppress harmonic current. In addition, with our original completely individual parallel operation controls, we attempted to strengthen our mid capacity lineup with high reliability and flexibility. Furthermore, we newly added a function that allows the device to reuse regenerative electric power and a peak-cut function that can control flicker by assisting the large power generated during extreme exertion of the motor. In other words, we worked to develop a 400 V parallel processing system voltage dip compensator with energy saving features, high quality, and high reliability. At this time, the inverter is operated as the parallel redundant operation with the commercial power supply, and at the same time it is performing active filter function to control the harmonic current and charging function to the battery simultaneously. That is to say, “power is supplied from the commercial power supply, and the quality is from the inverter” , where only the “quality” part is going through the inverter at the normal operation, so the electrical loss is significantly small compared to the constant inverter power supply system, shown in Fig. 1 (a), which goes through 2 convertors constantly, making it possible to supply the electricity with high efficiency and high quality.

3. Features of the “SANUPS C33A”

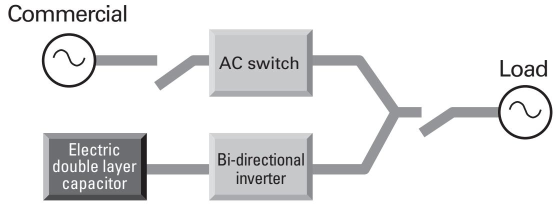
3.1 Basic structure

Fig. 1 shows the basic circuit structure of the UPS. (a) is the double conversion UPS, and (b) is the parallel processing type. The parallel processing type is adopted in the “SANUPS C33A” , in which the inverter is connected in parallel with the commercial power supply, and main electricity is supplied in the path with AC switch only. At this time, the inverter is operated as the parallel redundant operation with the commercial power supply, and at the same time it is performing active filter function to control the harmonic current and charging function to the battery simultaneously. That is to say, “power is supplied from the commercial power supply, and the quality is from the inverter” , where only the “quality” part is going through the inverter at the normal operation, so the electrical loss is significantly small compared to the constant inverter power supply system, shown in Fig. 1 (a), which goes through 2 convertors constantly, making it possible to supply the electricity with high efficiency and high quality.

To be able to expand the capacity efficiently and easily, the device uses the parallel processing type UPS as a base unit in order to enable construction of a parallel system. In general, when the UPS is operated in parallel, it is necessary to match the voltage magnitude, the phase, and the frequency since the output of each UPS unit is AC. If there are any differences in these, voltage differences will occur between each UPS unit. Also, since each UPS unit is connected with wiring only, the impedance between them is very small, but with the relationship of “current = voltage difference / impedance” , there will be excessive current running between each UPS unit even if the voltage difference is a small amount. This is known as “cross current” . In this case, each UPS unit will not be able to supply this excessive current, and so it will stop. The most secure way to control this cross current is to perform the parallel operation by making a control unit and distributing the common voltage, phase, and frequency commands to each UPS unit, as shown in Fig. 2 (a). But if there is a control circuit that is common to all, the whole system will halt when there is any malfunction in this control unit. So, even if the reliability of each UPS is very high, if the reliability of this common control unit is not as high, the reliability of the whole system will be low. Therefore, as shown in Fig. 2 (b), if each of the UPS units can operate in parallel without constructing a common control unit, the whole system can be made highly reliable without the dominance of the common control unit reliability. For

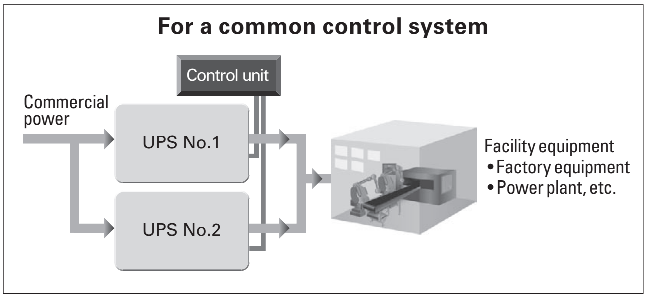


(a) Basic circuit structure of the double conversion UPS

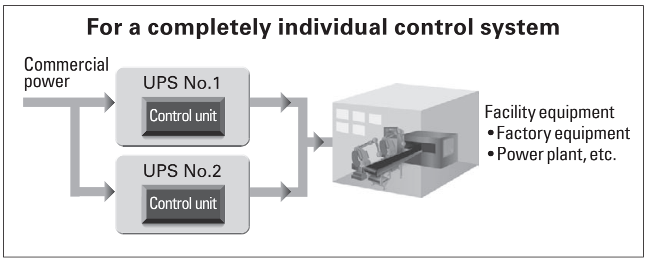


(b) Basic circuit structure of the parallel processing type

Fig. 1: Basic circuit structure of the UPS



(a) Common control system



(b) Completely individual control system

Fig. 2: Control system for parallel operation

high reliability in the whole system, the reliability of each UPS unit must be raised. But the parallel processing type that was adopted this time has less parts compared to the double conversion UPS and also the malfunction rate is low, therefore it is able to construct more reliable system.[1)]

3.2 Main features

This section introduces the main features providing high quality and high reliability.

3.2.1 Uninterrupted power supply characteristics and soft start function

This function is able to control the commercial power supply and inverter like it is constantly performing parallel redundant operations[2)], disconnect the commercial power supply in high speed with AC switch using our unique switching technology when there is a problem with the commercial power supply[3)], and then supply the electricity without interruption as shown in Fig. 3.

3.2.2 Active filter function

The active filter function uses the inverter to compensate the harmonic current and reactive power that occurred from load equipment and also controls the input current to be sine wave and the power factor to be 1. Fig. 4 shows the operation waveform of the active filter. The input voltage (commercial power supply) is distorted without the active filter function. In a voltage dip compensator without this function, this voltage distortion may affect other equipment that is connected to the same system, or it may cause malfunction of the power outage detection at the UPS.

3.2.3 Use of regenerative electric power

The voltage dip compensator uses an electric double layer capacitor (EDLC) as the accumulated energy source. It has superior charge-discharge characteristics compared to lead storage batteries, so charge and discharge can be performed actively.

With this, the regenerative power generated by operating load equipment, such as motors, can charge the EDLC without returning the regenerative power to the commercial power, and then this power can be reused on the load equipment. Fig. 5 shows the power pattern when regenerative power is generated. The regenerative power generated by the load equipment is not consumed by resistors, and instead charges the EDLC. Then, the power is used during the next extreme exertion of the motor, which can suppress needless power consumption.

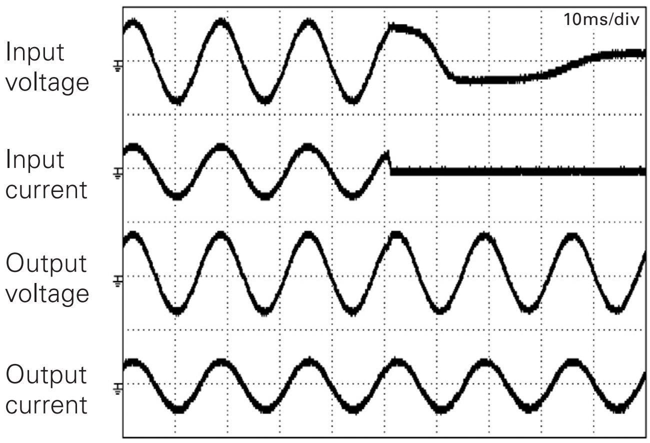


Fig. 3: Waveforms without interruption

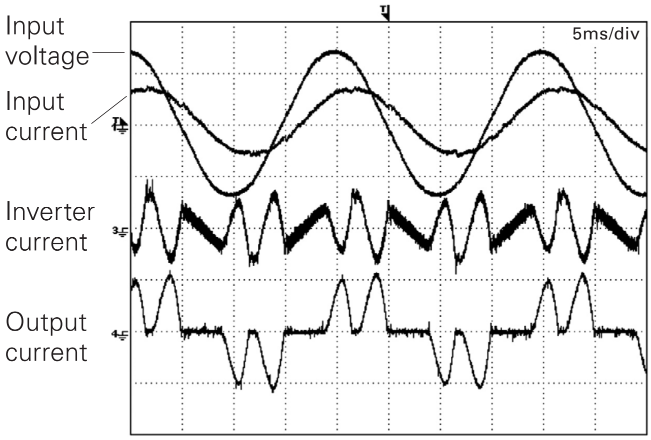


Fig. 4: Active filter operation waveform

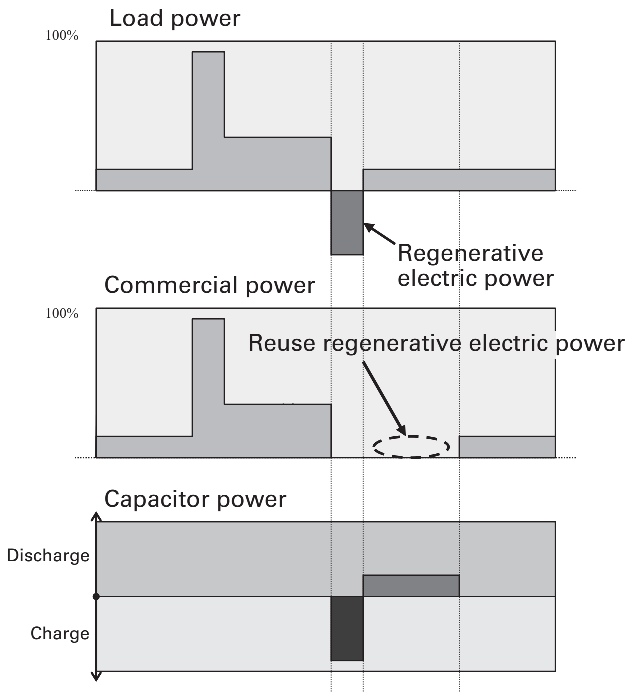


Fig. 5: Power pattern when regenerative power is generated

3.2.4 Peak-cut function

For the peak power of operating load equipment, load power that exceeds the set power for peak-cut can be stored in the EDLC and provide assistance in order to equalize the commercial power. Fig. 6 shows an example of the power pattern during peak-cut operations. Load power that exceeds the peak-cut setting is discharged from the EDLC and the EDLC is later charged for the amount of discharge, thus keeping the commercial power below the peak-cut setting and equalizing the electric power. This function can suppress flicker in the commercial power supply and decrease the costs of power receiving equipment.

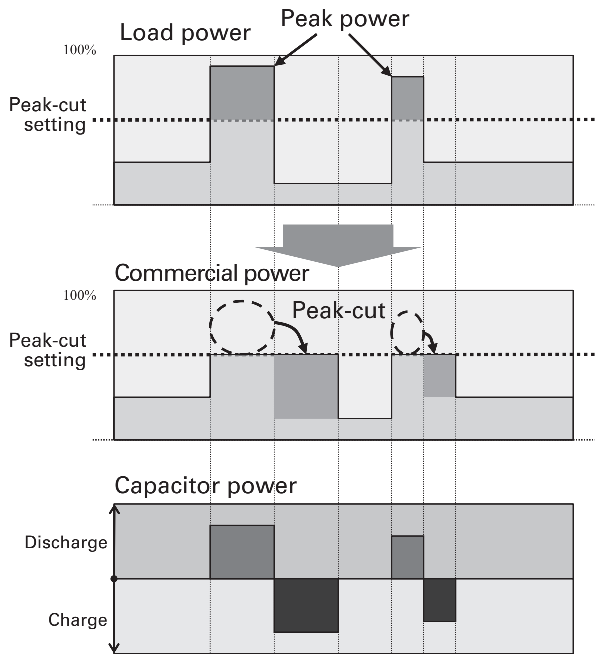


Fig. 6: Power pattern during peak-cut operations

4. Specifications

Table 1 shows the basic specifications. Fig. 7 shows the external appearance of the developed “SANUPS C33A” 150 kVA UPS unit. The 150 kVA voltage dip compensator is the smallest in the industry, designed to be small size with dimensions of 700 mm (W) x 800 mm (D) x 1950 mm (H) and mass of 550 kg.

The lineup consists of a 150 kVA model and a 300 kVA model with the 150 kVA base UPS unit. The model uses completely individual parallel operation control so that it can be easily expanded in the future for further add-on capacity. Except in cases with only a single unit, a system is constructed with an I/O power board combining N numbers of UPS and the UPS units. If an I/O power board for the maximum power supply capacity is installed at the beginning, each UPS unit can be installed separately in accordance with the systematic plan. The model is also constructed with an EDLC board, and it is compatible with both individual EDLC boards that are installed for each UPS unit and also centralized EDLC boards where the EDLC is shared by all UPS units.

Furthermore, if N number of multiple units are used, then even if one UPS unit breaks down, operations can be returned to normal manually as long as the load remains below the capacity for N-1 units. This attempts to shorten the mean time to repair.

Fig. 7: Developed “SANUPS C33A”

Table 1: Basic specifications

Item			C33A154	C33A304	Remarks
Rated capacity			150 kVA	300 kVA	
Rated output			120 kW	240 kW	
Board structure			Steel-sheet independent board closure type (Protection class IP2X)		
Operation system			Parallel processing type		Double conversion parallel type
Cooling method			Forced air cooling		
Storage element			Electric double layer capacitor		
AC input	No. of phases/wires		Three phase, three wire		
	Rated voltage		420 V (380, 400, 415 V)		
	Rated frequency		50 Hz or 60 Hz		
	Distorted current compensation	Compensation capacity	Within rated capacity		
		Harmonic current	Compensation rate 75% or higher		At 100% wave rectifier load
		Compensation order	2 to 20 order harmonic		
	Input power factor		0.97 or higher		During rated operations
AC output	No. of phases/wires		Three phase, three wire		
	Rated voltage		420 V (380, 400, 415 V)		Same as AC input
	Voltage precision	At commercial parallel operation	Rated voltage within -8% and +10%		Setting can be changed
		At capacitor operation	Rated voltage within ±2%		Note 1
	Rated frequency		50 Hz or 60 Hz		
	Frequency precision	At commercial parallel operation	Rated frequency within ±4%		
		At capacitor operation	Rated frequency within ±0.1%		Note 1
	Load power factor	Rated	0.8 (lagging)		
		Variation range	0.7 to 1.0 (lagging)		Note 2
	Voltage wave form distortion factor (At capacitor operation)	Linear load	2% or less		
		Wave rectifier load	5% or less		
	Voltage unbalance ratio (capacitor operation)		Within 2%		Enter load of 1/3 total capacity on one line
	Transient voltage fluctuation (At capacitor operation)	Variation rate	Within ±5%		
		Settling time	Within 50 ms		
	Overload capacity (direct circuit)		200% (30 seconds), 800% (0.5 seconds)		
	Overcurrent protection		At 110% rate output, the inverter stops and commercial direct power is supplied. When it becomes less than the rated current, the inverter automatically starts and normal operations resume.		
	Output power regeneration processing	Max. regenerative electric power	50% or less		Compared to equipment rating
		Max. amount of regenerative electric power	150 kWs	300 kWs	
	Time for switching to capacitor power supply		0 seconds (without interruption)		
	Voltage dip compensation time		1 second or more (during rated load)		Note 3
	Initial charge time		Within 60 seconds		From capacitor voltage 0% to 100%
	Recharge time		Within 10 seconds		After rated compensation for 1 second instantaneous drop
Acoustic noise			70 dB or less		A characteristics
Environment			Ambient temperature: 0 to 40˚C, Relative humidity: 30 to 90% (no condensation)		

Note 1: Indicates the inverter capabilities when switches to capacitor operation from rated input voltage and rated frequency.
Note 2: Continuous state (short-term fluctuations permitted within the max. amount of regenerative electric power)
Note 3: Rated load: During load power factor 80% (lagging) and ambient temperature 25˚ C. The voltage dip compensation time can be extended.

5. Conclusion

We introduced the product overview for the 400 V large capacity parallel processing type “SANUPS C33A”. In this development, we established a completely individual parallel operation control system that is able to perform parallel operation easily, so we are planning to improve the series by expanding the equipment capacity.

Documentation

1) Y. Okui, S. Ohta, N. Nakamura, H. Hirata and M. Yanagisawa, “Development of Parallel Processing Type UPS Using a Novel Independent Control for Parallel-Connected UPS Units”, Proceedings of IEEE International Telecommunications Energy Conference (INTELEC '09), PC8-3, 2009.
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