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MEDIUM UNINTERRUPTIBLE POWER SYSTEMS WITH MOSFETS

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1. FOREWORD

In the rapidly advancing information-oriented society the uninterruptible power system (UPS) is becoming widely popular as a power supply system which supplies high reliability and high-quality electric power to computer systems and information network systems which supports its nucleus.

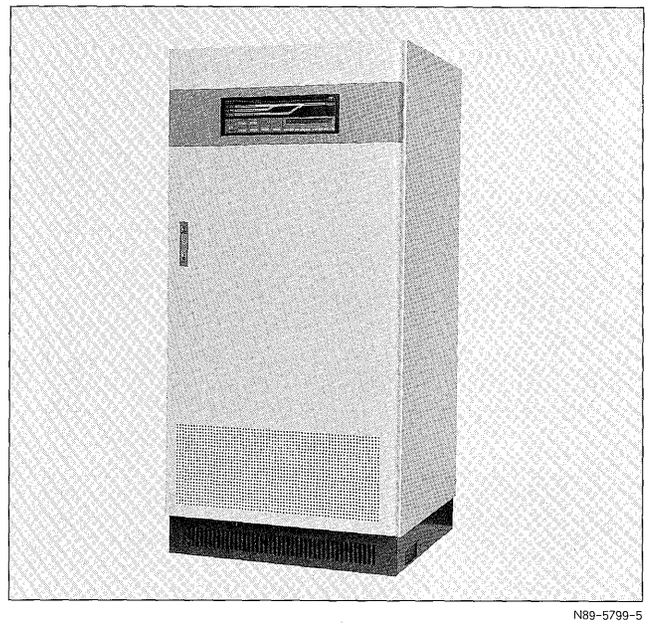
Especially, the advance (miniaturization, higher performance) and popularity of the computer in recent years has been noticeable. Computers with the capacity comparable to that of conventional large general-purpose computers have been miniaturized so that they can be installed even in general offices, etc.

In step with this, UPS which can be installed next to the computer, that is, in general offices, computer rooms, etc. are also being demanded.

The newly developed medium UPS with MOSFETs "UPS600-043/063" are high-performance, user friendly, quiet, and compact and meet the recent need for low noise uninterruptible power.

The UPS600-043/063 are outlined here.

Fig. 1 Exterior view of UPS600-063 (50 kVA)



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2. FEATURES

The UPS600-043/063 have the following features:

(1) Compatible with switched-mode power supply

A power metal-oxide semiconductor field effect transistor is used as the switching elements and power up to 100% capacity of the output rating can be supplied while keeping the output voltage a sine-wave even for switched-mode power supply and other high peak current computer loads with numerous harmonics by performing high-frequency pulse width modulation (PWM) with instantaneous value control. (Output voltage wavevform distortion 5% or less for 100% non-linear load)

(2) Excellent dynamic response

The transient output voltage change was made ±5% or less by sudden load change (0↔100%) and strength against load inrush, etc.

(3) High unbalanced load strength

For the 3-phase output UPS600-063, since the output voltage unbalance was made ±3% or less even for 100% unbalance load (single-phase load of rated line current connected between one line only), there is no need to be conscious of the balance between phases of the load and single-phase load can be connected.

(4) User friendly

A control panel which displays the UPS internal digit metering, operation guidance, faulty diagnostics, etc. by backlighted liquid crystal display is standard so that the UPS can be operated easily even without a special operator.

(5) Compact

The size and weight of the transformers, inductors, capacitors, and other components by increasing the frequency by using fast switching speed power MOSFETs and substantial miniaturization was realized so that the system can be installed in an office, computer room, and other restricted spaces. (Volume: 65% of old Fuji type 50 kVA system)

(6) Low noise

Quietness of 55 phons or less suitable for installation in the living environment of the office, computer room, etc. was realized.

3. STANDARD SPECIFICATIONS

The standard specifications of the UPS600-043/063 are shown *Table 1*.

The UPS600-043/063 are serialized from 20 kVA to 50 kVA. The specifications of each had a non-linear load (switched-mode power supply) as the precondition.

4. COMPOSITION

4.1 Main circuit system

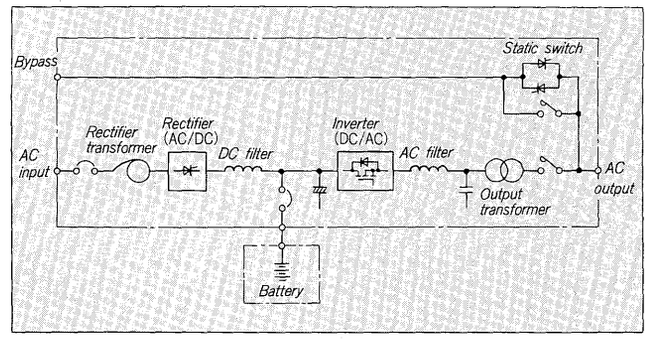
The main circuit system of the UPS600-043/063 is shown in *Fig. 2*.

A battery charger system using a thyristor, that is, charger input system (floating system), is used at the rectifier which converts the AC input to DC.

The features of this system are that the battery is continuously connected to the inverter input and it does not have a battery switch (semiconductor switch) and reliability as a power supply is extremely high.

The inverter performs high-frequency PWM control and generates an AC voltage and removes the harmonics of the modulation frequency components by means of a small AC filter and supplies a sine-wave voltage to the load through an output transformer.

Fig. 2 Main circuit system



An uninterruptible back-up system with bypass as back-up is used as a high reliability system. This system normally supplies power to the load from an inverter operated synchronously with the bypass and performs no break transfer to the bypass when an overload or failure occurs.

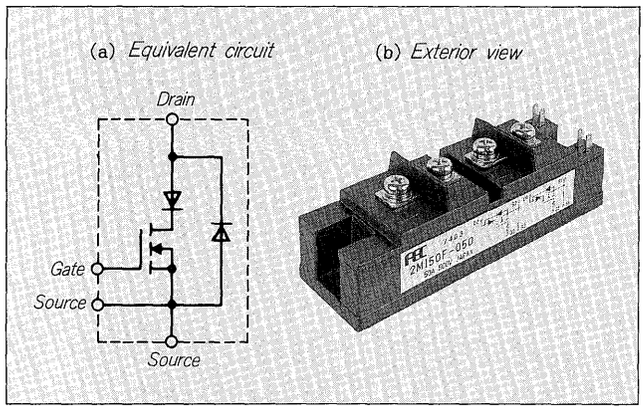
4.2 Inverter main circuit elements and drive circuit

A Fuji Electric power MOSFET module (*Fig. 3*) is used as the semiconductor of the main circuit of the inverter. For high current capacity, up to eight modules are paral-

Table 1 Standard specifications

Item		Model: Single-phase output 043/20	Single-phase output 043/40	3-phase output 063/30	3-phase output 063/50	Remarks
Input	Voltage	200V±10%				
	Frequency	50Hz or 60Hz±5%				Selectable with switch
	Number of phase and number of wires	3-phase, 3-wire				
Output conditions	Capacity	20kVA/16kW	40kVA/32kW	30kVA/24kW	50kVA/40kW	
	Voltage	100V		200V		
	Frequency	50Hz or 60Hz				Selectable with switch
	Number of phase and number of wires	Single-phase, 2-wire system		3-phase, 2-wire system		
	Lead power factor	0.6 (lagging) ~ 1.0 Rated 0.8 (lagging)				
	Voltage accuracy (when settled)	±1.5%				
	Transient voltage change	① 0↔100% sudden load change : ±5% ② 15% sudden input voltage change : ±5% ③ Utility power interruption and recover : ±5% ④ UPS↔Bypass switching : ±10%				However, item 1. to 4. shall not overrap.
	Response time	100ms				
	Waveform distortion	3% (all harmonics square average value at a 100% linear load) 5% (all harmonics square average value at a 100% non-linear load)				
	Voltage unbarance between phases	–		At a 100% unbalance load : 3%		Within rated phase current
	External synchronization range	±1%				
	Allowable maximum peak current	2.4 times effective value of rated phase current				
	Overload resistance	10				
Battery	Rated voltage	288V		240V		
	Back-up time	10 mins at a 100% load, 30 mins at a 50% load				
Noise (average)		53dB	55dB	55dB	55dB	A range at 1m

Fig. 3 Power MOSFET



leled. The power MOSFET has the following features:

(1) Since it is a multicarrier devices, switching speed is intrinsically fast and it is suitable for high frequency applications.
(2) Since it is a voltage control type device, drive power is small.
(3) Because the on resistance temperature coefficient is positive, paralleled operation is easy and current concentration occurs with difficulty. Therefore, there is no secondary breakdown and the safe operation area is wide.

For the power MOSFET drive circuit, the size of the pulse transformer as reduced by using high frequency signals 180° out of phase as the two pulse transformer drive signal.

A snubber circuit which absorbs the energy stored in the wiring inductance when the power MOSFET is turned off by a lower surge voltage was used.

Optimum high speed switching is realized by means of these drive and snubber circuits.

4.3 Control circuit

The inverter control circuit block diagram is shown in *Fig. 4*.

High-frequency pulse-width modulation method with instantaneous value control was used as the control method.

This method consists of a triangle wave circuit made up of an up/down counter and D/A converter, sine-wave circuit made up of an address counter and PROM and multiplying mode D/A converter, instantaneous value controller, comparator, logics, voltage and current limiter controller, instant current limit circuit, etc.

With the 3-phase UPS600-063, output voltage low distortion and excellent unbalance load characteristics were realized by sharing the voltage and current limit controller and triangle wave circuit and providing a sine-wave circuit, instantaneous value controller, comparator circuit, logics, instant current limit circuit, etc. for each phase.

The AC output of an inverter generally contains a DC voltage component due to control circuit drift, main circuit element switching speed variations, etc. Since the DC component generated by the inverter was detected and the voltage setting sine-wave was biased so that this component becomes zero so that the inverter output transformer is asynmmetrically magnetized by this DC voltage component and magnetic saturation does not occur, the DC voltage component generated by the inverter was eliminated and the flux density of the output transformer could be increased, a compact output transformer was realized.

4.4 Exterior views and outline dimensions

The exterior view of a UPS600-063 50 kVA system is shown in *Fig. 1*. The outlines dimensions and weight of the UPS600-043/063 are shown in *Fig. 5*.

The exterior view, outlines dimensions, and weight have been developed with installation in an office or com-

Fig. 4 Inverter control circuit block diagram

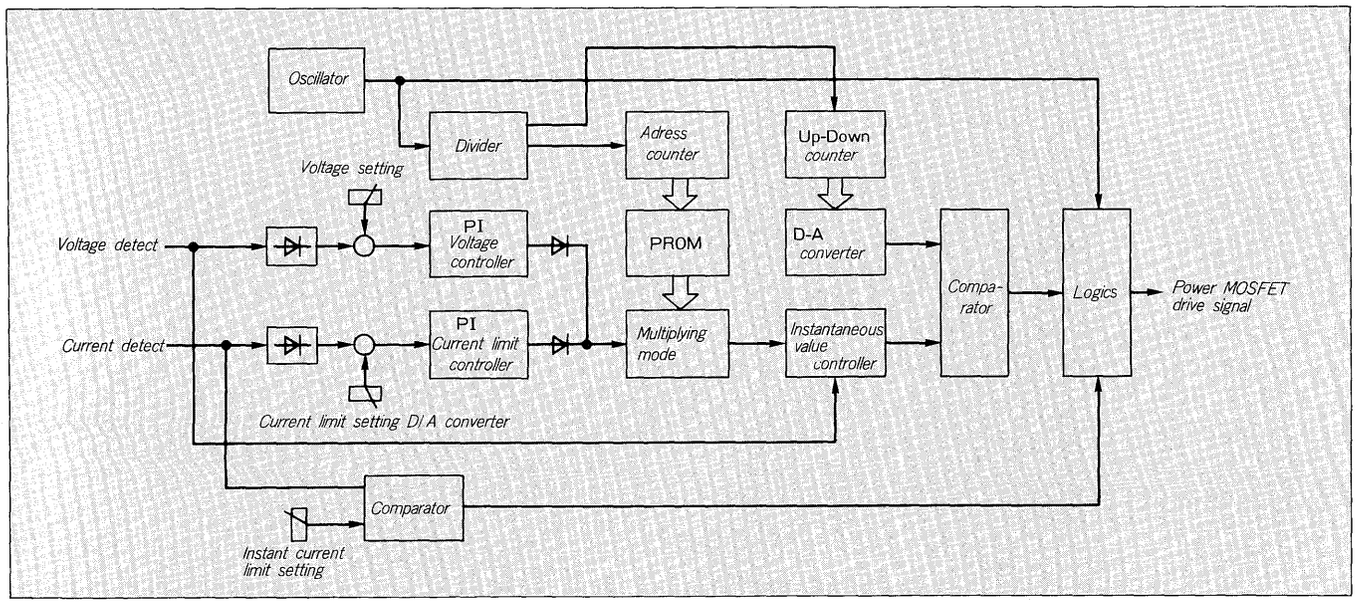
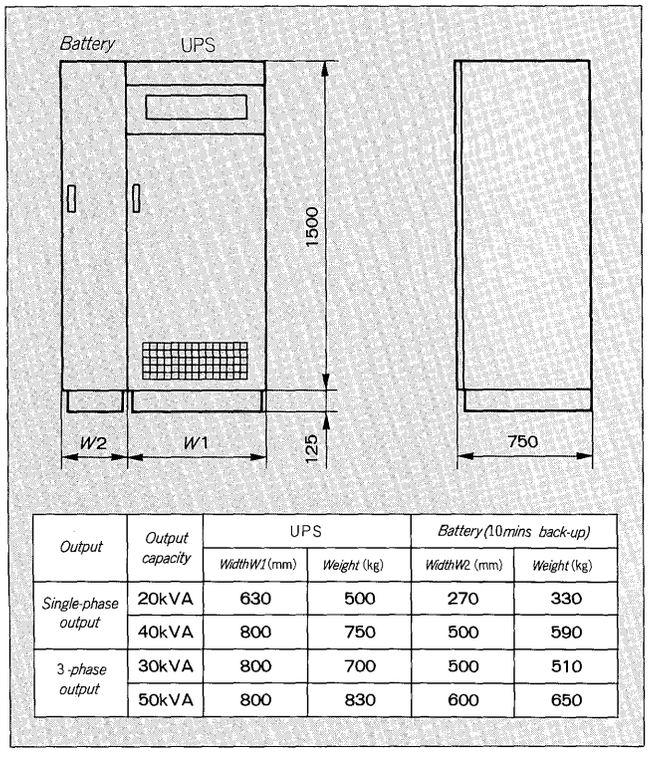


Fig. 5 Dimensions and weight



Output	Output capacity	UPS		Battery (10 mins back-up)	
		Width W1 (mm)	Weight (kg)	Width W2 (mm)	Weight (kg)
Single-phase output	20kVA	630	500	270	330
	40kVA	800	750	500	590
3-phase output	30kVA	800	700	500	510
	50kVA	800	830	600	650

puter room as a precondition.

To express the image of the UPS and OA equipment, the corners were rounded and the body color was made off white (5GY8, 5/0.5) as standard and the equipment was designed to adapt to the installation environment.

The equipment depth dimension was made 750 mm and the construction was made such that it could be divided into UPS and battery and delivery by elevator was made possible.

The interior uses a tray construction, plug-in type unit construction, etc. (battery tray, inverter unit, fan unit, etc.) so that maintenance checks of both the UPS and battery can be performed easily from the front and rear maintenance space is unnecessary.

This reduced installation environment restrictions substantially.

5. MAN-MACHINE INTERFACE

5.1 Control panel

The flat command switches, light emitting diodes (LED), an backlighting liquid crystal display (LCD) are grouped on a sheet keyboard and are controlled by a microcomputer. An exterior view of the control panel is shown in *Fig. 6*.

(1) Status display

The nature of the control panel has a status display was emphasized and the system diagram was illustrated and summarized graphically. Twelve LEDs are provided at the end of the system diagram. The system which is supplying power is expressed by lighting these lamps cyclically in a

Fig. 6 Control panel

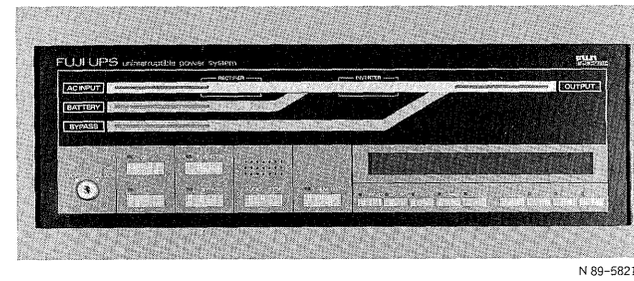


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Fig. 7 Actual measurands display

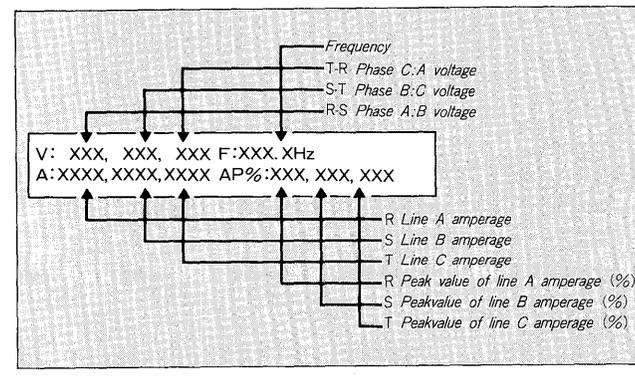
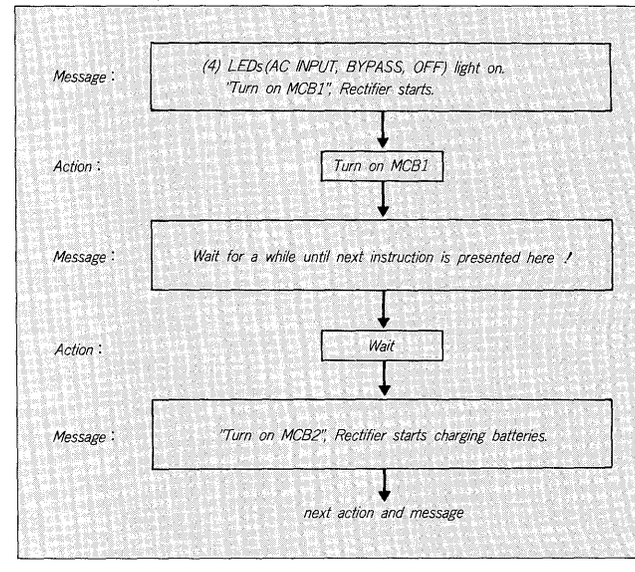


Fig. 8 Operation guidance



neon state. The supply state is grasped at a glance and there is no devotion to one function. This character-filled expression is considered to given a desirable image suitable for the installation environment.

(2) Running operation

Operation was made double movement operation by which key switches are operated by setting them to the unlock state so that the system is not stopped by mistake.

(3) Measurement

Measurement is performed by selecting switches which show the measurement points below the LCD. When a switch is selected, the LCD backlighting is turned on so that the voltage, current, and frequency of that point are

displayed together on a 40 x 2 digits LCD. Therefore, individual selection of the voltage and current is unnecessary. Since the LCD display does not have to be watched constantly, when the same switch is reselected or operation is not performed within a fixed time, the display goes off automatically. (Fault diagnostics to be described later does not go off). An actual measurements display is shown in *Fig. 7.*

(4) Operation guidance

Operation guidance is performed by selecting the guidance switch (F2) at the bottom of the LCD. The operation to be performed next by the operator is displayed sequentially on the LCD according to the stage. Therefore, it can be operated easily by anyone. Operation guidance examples are shown in *Fig. 8.*

(5) Fault diagnostics

When a fault occurs, a message corresponding to the condition is automatically displayed on the LCD. When the power fails, the elapsed battery operation time is displayed so that the operator can make computer memory save and other correct judgments.

(6) Maintenance guidance

Maintenance guidance is performed selecting guidance switch (F3) at the bottom of the LCD. The fan replacement time and other maintenance information are displayed.

(7) Recording

Recording is performed by selecting guidance switch (F1) at the bottom of the LCD. The number of battery operations and system operating time are displayed. This data is recorded in an NVRAM (Nonvolatile RAM). This information is for maintenance and other purposes.

5.2 Serial interface

One T-link port was provided as standard and one RS-232C port was made available as an option.

These ports are controlled by separate microcomputer independently from the operation display function.

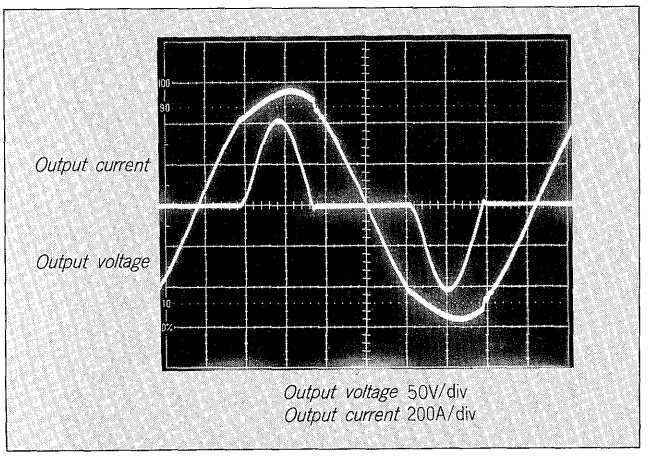
(1) T-link port

The multidrop type T-link used in serial transfer between terminals of the Fuji programmable controller MICREX-F Series was installed. On the one hand, the T-link is used in transfer to display the status inside the system, one end ofthe link is open to outside the system. Therefore, remote operation and extraction of display signals are possible by connecting a MICREX-F I/O capsule. When a MICREX module is connected, connection to the MICREX mainframe is possible. In this case, sequence control matched to the system of the equipment, etc. are possible.

(2) RS-232C port

Remote monitoring of the system by personal computers, etc. is possible by installing an RS-232C port as an option.

Fig. 9 Output voltage waveform for 100% single-phase non-linear load (20 kVA UPS)



6. TEST RESULTS

The test results for typical characteristics of this system are shown below.

6.1 Output voltage waveform for rectification load

The output voltage and output current waveforms for a 100% single-phase non-linear load (20 kVA UPS) are shown in *Fig. 9* and the output voltage and current waveforms for a 100% 3-phase non-linear load (50 kVA UPS) are shown in *Fig. 10.*

Since high-frequency PWM control with instantaneous value control function was performed and the AC filter was miniaturized, the output voltage waveform distortion is a good 4.2% even when supplying power to a load with

Fig. 10 Output voltage waveform for 100% 3-phase non-linear load (50 kVA UPS)

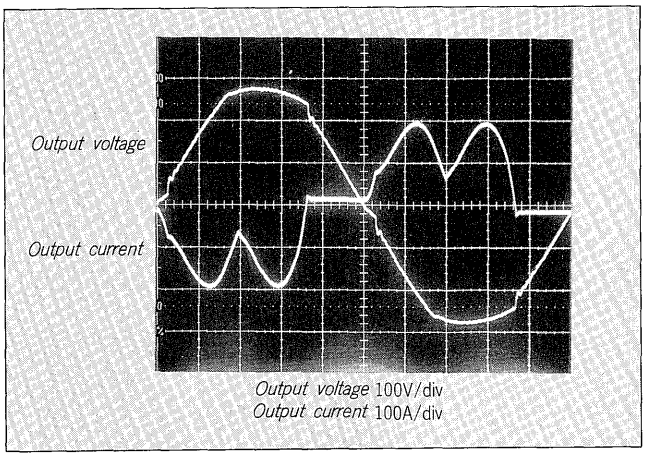


Fig. 11 Waveform at 100% sudden load change

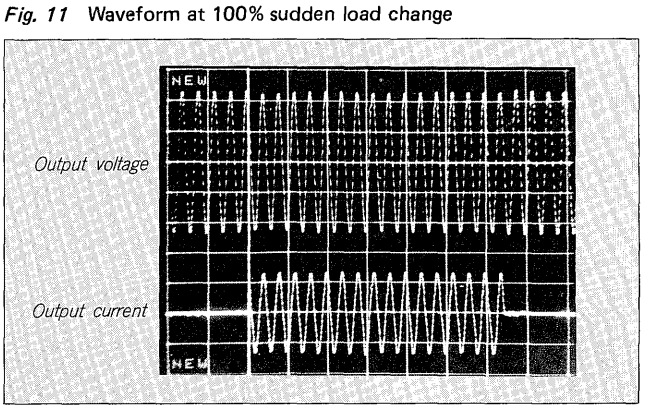
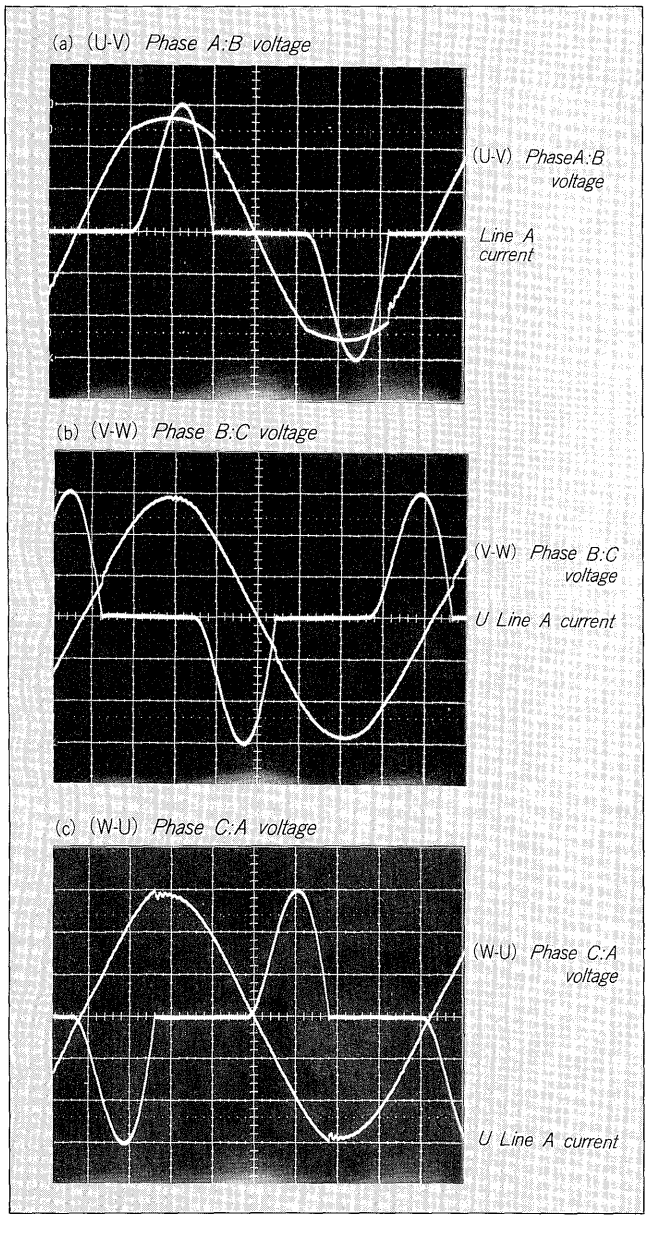


Fig. 12 Output voltage waveform for a 100% unbalance load



a large harmonic content and low-distortion stable AC power can be supplied to the capacitor input type rectification load inside a computer.

6.2 Output voltage transient change at sudden load change

The output voltage and output current waveforms for a sudden load change (0↔100%) are shown in *Fig. 11.* The transient change of the output voltage is made small (±4.3%) by the instantaneous value control described above and the characteristic is very good even for 100% load changes.

Table 2 Characteristics of unbalance loads (50kVA UPS)

Load conditions			Non-linear load	Linear load
Effect value of output current	A	A	140.4	144.0
	B		140.4	144.0
	C		0	0
Effect value of output voltage	A : B	V	196.4	195.0
	B : C		201.6	202.0
	C : A		203.2	204.6
Wave form distortion	A : B	%	4.50	0.88
	B : C		2.49	1.10
	C : A		2.45	0.99

Because of this, even when multiple devices are connected to the UPS, each load can be turned on and off without affecting the other load devices.

6.3 Output voltage for unbalanced load

The output voltage waveform when a single-phase rectification load with an rms value of the rated line current was only connected between the U-V line for 3-phase output 50 kVA UPS is shown in *Fig. 12.* The characteristics for unbalanced rectification load and linear load are shown in *Table 2.*

By providing three sets of single-phase inverters and controlling the instantaneous value of each phase individually, the maximum output voltage interphase voltabe unbalance became –2.5% and the maximum output waveform distortion became 4.5% even for very unbalanced (single phase load connected only between one line) and rectification loads.

Therefore, it can be used without paying any attention to single-phase load balancing even when single-phase and 3-phase loads are mixed.

7. CONCLUSION

The Fuji medium UPS with power MOSFET suitable for high frequency switching "UPS600-043/063" was introduced. We are confident that this product meets the needs of the market which will demand medium UPS of the future and is connected to higher performance, lower price, and greater compactness of the UPS.

The UPS duty of the UPS will become steadily more important in the rapid advance of the information orientation.

Fuji Electric will assimilate new technology positively and advance development and commercialization of the power supply systems matched to the needs of all users.