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STABILIZED POWER SOURCE FOR COMPUTERS

Takeshi Abe
Hideo Ishibashi
Matsumoto Factory

I. INTRODUCTION

Computers are now being utilized in many fields such as office work, factory operations and scientific calculations. Computers are becoming much larger both in termes of capacity and capability which means that the power sources must also be larger and considerable stress must be placed on performance and reliability.

Fuji Electric has manufactured and delivered a large number motor generator (M-G) type power sources to supply stabilized power to computers. This type of equipment is severely limited, however, in respect to noise, vibrations and installation site. For these reasons, this type of power source is now being replaced by constant-voltage, constant frequency (CVCF) type which employ thyristor inverters, are compact and can be installed anywhere.

This article will introduce a 200 kva CVCF power source using an ac-dc-ac system which was manufactured by Fuji Electric for the Kawasaki factory of Fujitsu Ltd.

II. FEATURES OF THE FUJI STATIC-TYPE CVCF POWER SOURCE EQUIPMENT

The circuitry and overall structure of this equipment has been especially designed to provide high reliability and easy maintenance. The main features are as follows.

1) Only a small area is required for installation and it can be installed just about anywhere.

Since there are very few operating parts in comparison with the M-G system, there are almostno vibrations or noise and a foundation is unnecessary. This means that there are almost no limits as to the installation site and the equipment can even be located on the upper stories of a building.

2) Maintenance and inspection are simple

Since there are almost no parts subject to wear, little maintenance is required and maintenance and inspection are facilitated by the use of unit construction for each component.

3) Reliability is improved by the use of the forced commutation system(1)

Since commutation circuits are especially important for the thyristor inverter, Fuji Electric employs a forced commutation system. With this system, reliable commutation is guaranteed when there are variations in the source voltage and the load. High efficiency is ensured since power losses due to commutation are very low.

4) Highly reliable thyristor cells are used

The thyristors employed in the inverter have excellent switching characteristics (di/dt, dv/dt. turn-off time etc.) and very stable characteristics.

5) Waveform distortion is low and stability against unbalanced loads is high

Due to the special connection method for the

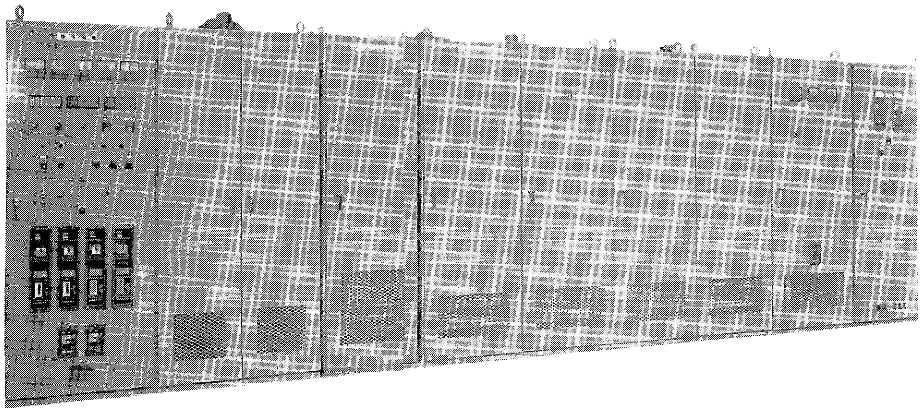


Fig. 1 External view of 200 kva CVCF power source equipment

Table 1 Specifications of 200 kva CVCF Power Source Equipment

	Item	Specifications
Input	Input voltage and variation	3300 v±10%
	Input frequency and variation	50 Hz $^{+1\ Hz}_{-2\ Hz}$
	No. of Input phases and lines	3-phase 4 w
	Dc intermediate circuit voltage	Dc 250 v
Output	Output capacity rated	200 kva
	maximum	250 kva (1 min.)
	Output voltage and accuracy	200/100 v±1.5%
	Variable range for output voltage	200/100 v±5%
	Output frequency and accuracy	50/60 Hz±1%
	Variable range for output frequency	50/60 Hz±3 Hz
	No. of output phases and lines	3-phase 4 w
	Load power factor	0.8~1.0
	Waveform distortion	7% or less
	Amount of unbalance in output voltage	Unbalance of line voltage: 4 v or less (when unbalance load is ±20%)
	Transient voltage variation	±7% (when input voltage variation is 10%) ±7% (when load variation is ±20%)
	Efficiency	80% or over

secondary windings of the output voltage transformers and use of the unit inverters (6-pulse inverter), waveform distortion is low and balanced output can be obtained when there are 3-phase unbalanced loads.

6) Frequency accuracy is high

Since an oscillator determines the output frequency, high accuracy is obtained without any adverse effects from power source or load variations.

7) An overload current limiting system is provided

III. OUTLINE OF THE CVCF POWER SOURCE EQUIPMENT

1. Specifications

The specifications of this 200 kva CVCF power source equipment are given in *Table 1*. This equipment is designed so that it can also be used in the future as an uninterruptable power system by the inclusion of a battery charger, battery and thyristor switch.

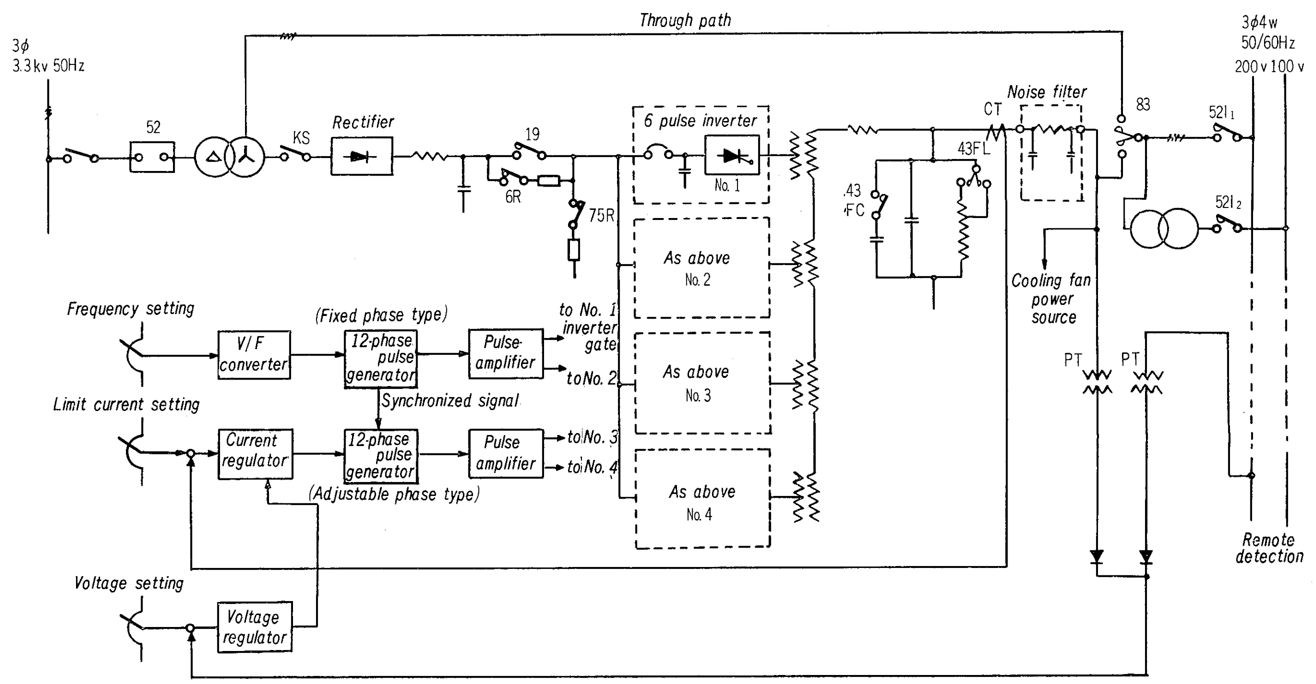


Fig. 2 Skeleton diagram of 200 kva CVCF power source equipment

2. Outline of the Equipment

A skeleton diagram of this equipment is shown in *Fig. 2*. The equipment is fed 3.3 kv which it steps down to 3-phase 4-wire ac 200 v by means of a step down transformer. Dc power is then supplied to four 6-pulse inverters (No. 1∼No. 4) via a rectifier and a smoothing filter. Inverters No. 1 and No. 2, and inverters No. 3 and No. 4 operate with a fixed phase difference between them of 30° el, and with this arrangement the harmonic components cancel each other so that the output voltage waveform is almost perfectly sinusoidal. However, by adjusting the phase difference (α) between inverters No. 1 and No. 2 and inverters No. 3 and No. 4, it is possible to control the output voltage.

The unit inverter (6-pulse inverter) is a 165° conduction type forced-commutation inverter as shown in *Fig. 3*. This type of inverter insures stable operation and high efficiency with very little variation in the output voltage waveform. The secondary windings of the 6-pulse inverter output transformers are connected as shown in *Fig. 4*, so that a 3-phase 4-wire system is possible and improvements can be made in the output voltage waveform as well as reductions in the amount of output voltage unbalance in respect to 3-phase load unbalances.

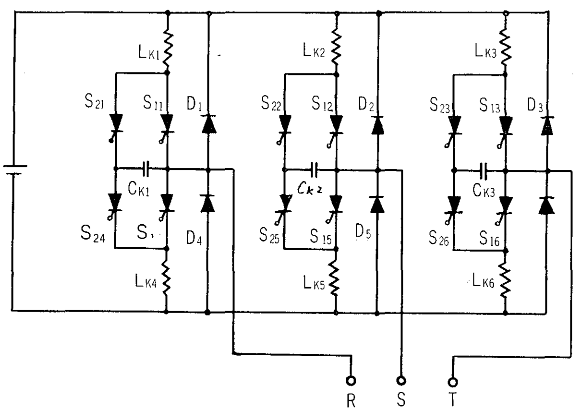


Fig. 3 Three-phase inverter connection with forced commutation

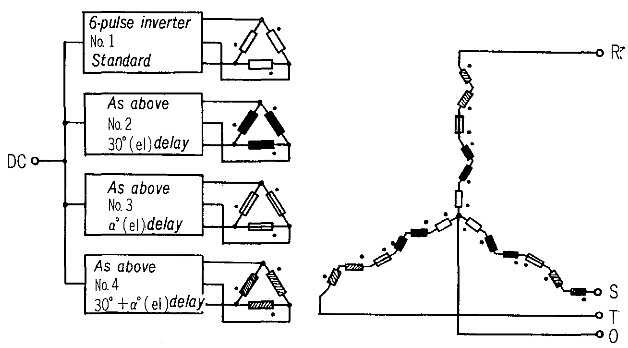


Fig. 4 Connection of output transformer

Details of the operating principles of the forced commutation inverter and the multiple inverter connection method will not be given here since they have already been dealt with in other articles.(1)(2)(3)

The output frequency of the equipment can be either 50 or 60 Hz, but by switching one part of the sine wave filter, ac power can be supplied to the load with little waveform distortion at either of these two frequencies.

Fig. 5 shows an interior view of the 200 kva CVCF power source equipment. As can be seen from this figure, the thyristors and diodes are arranged in Fuji Electric's standard thyristor and diode unts. Since the control equipment checking jacks are placed in tray type or printed board units, maintenance and inspection are both easy and efficient. The distribution panels consist of, from the right, (1) a high voltage receiving cubicle, (2) a rectifier cubicle, (3) Inverters No. 1∼No. 4, (4) an inverter control cubicle, (5) output filter cubicle, (6) an operation distribution cubicle, and (7) a remote control operation cubicle.

3. 165° Conduction-Type 6-Pulse Inverters

The 6-pulse inverters, as shown in *Fig. 3*, have a conduction angle of 165° for the main thyristors (S_{11}–S_{16}). In the case of self commutated inverters, conduction angle of a main thyristor is fixed on 180° and the output voltage waveform is held constant no matter what the load conditions. However, when the thyristor conduction angle is 180°, energy arising during the commutation process circulates in the thyristors, diodes and commutation reactor and is consumed, but this defect leads to a decrease in the efficiency and also the current capacity of the circuit elements must be increased. In order to eliminate this effect, Fuji Electric generally employs 120°

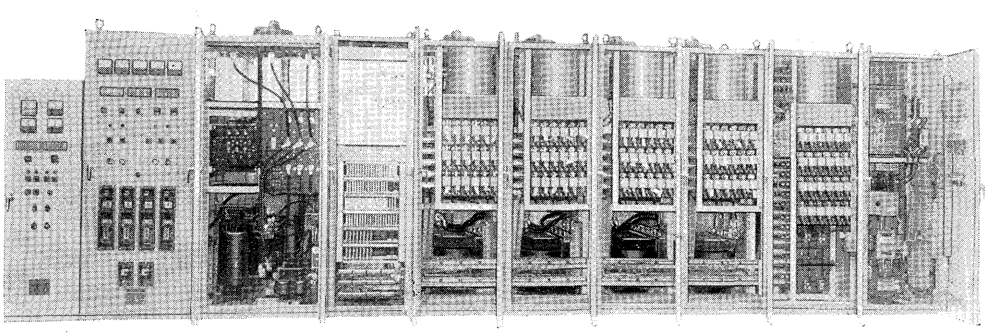


Fig. 5 Interior of 200 kva CVCF power source equipment

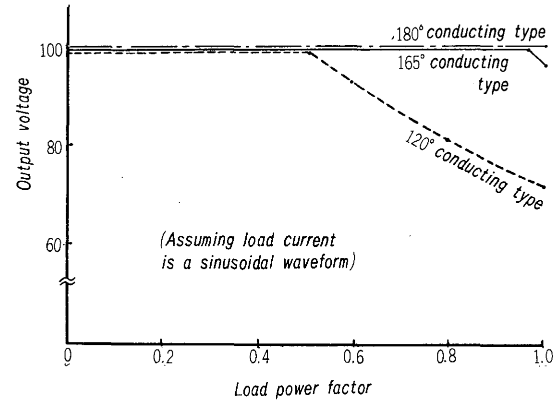


Fig. 6 **Voltage regulation of three phase inverter**

conduction type forced-commutation inverters in all inverter circuits used to drive ac motors.

However, the lower the main conduction angle value becomes below 180°, the greater are changes in the inverter output voltage waveform, i.e. the effective output voltage value, due to changes in the load power factor. Therefore in stable power source equipment, it is best not to have the conduction angle too much below 180°. For this reason, this equipment employs a conduction angle of 165°. *Fig. 6* shows the voltage regulation of 6-pulse inverters with these three different conduction angles: 180°, 165° and 120°.

IV. CHARACTERISTICS

As was described above, this equipment contains four 165° conduction type forced-commutation inverters which allow for stable inverter operation, improved efficiency and a minimum of output voltage waveform distortion. However, these can be changed depending on the desired results. The load characteristics of this equipment are shown in *Fig. 7*. The overall efficiency is 85.4% and the inverter side efficiency is even higher, 90% or over.

One of the points which merits attention in this equipment is that the same high efficiency is maintained at all loads from very light to total capacity

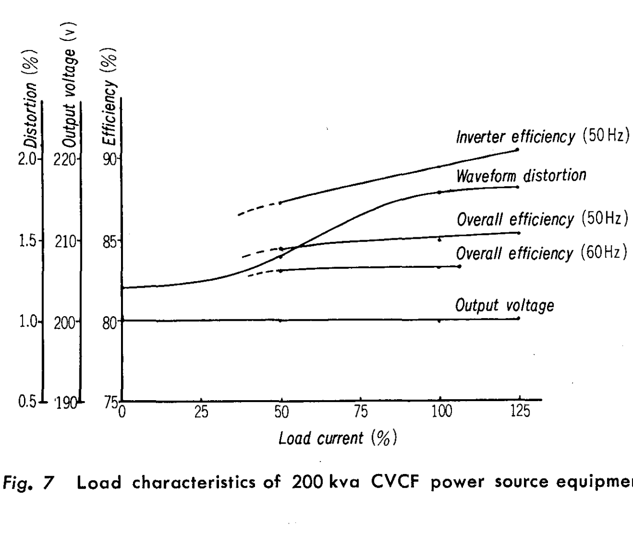
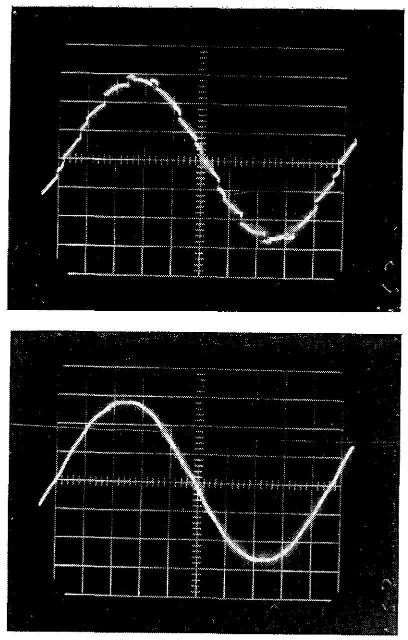


Fig. 7 **Load characteristics of 200 kva CVCF power source equipment**



(a) Filter input side voltage waveform

(b) Filter output side voltage waveform

Fig. 8 **Voltage waveforms**

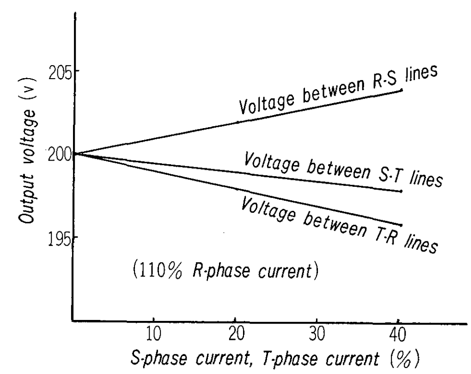


Fig. 9 **Output voltage with unbalanced load**

loads. This is due to the fact that the commutation energy changes in accordance with the size of the load, which is not the case in the W. McMurray type self commutated inverter[(4)] for instance, where an almost constant commutation loss occurs no matter what the load.

The output voltage waveform distortion is only 1.8% even at maximum load (125% load) which proves the effectiveness of the 165° conduction-type 6-pulse inverter and the multiple connection method. *Fig. 8* shows the input and output voltage waveforms of the sine wave filter during maximum load.

As was described earlier, the problem of 3-phase output voltage unbalances in respect to 3-phase load unbalances was greatly improved by keeping the main thyristor conduction angle of the 6-pulse inverter as near to 180° as possible and also by means of the transformer secondary winding special connection method. On the control side, a 3-phase single unit control system which prevents unbalances in any of the phases is used. *Fig. 9* shows the output voltage characteristics in respect to a 3-phase un-

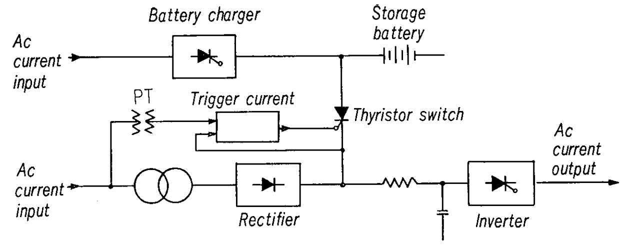


Fig. 10 Block diagram of uninterruptable power source

balanced load. In order to balance this output voltage when there is an unbalanced load, the only method is to perform feedback control for each phase. However, as long as the degree of load unbalance is not especially large, the 3-phase single unit voltage control system can be used in practice without any problems.

V. UNINTERRUPTABLE POWER SOURCE SYSTEM

Starting and stopping of power source equipment stabilized by means of thyristor inverters can be done very quickly. This equipment has such features as rapid response etc, but there is no means of energy storage like that performed by the flywheel in the M-G system. Therefore, when the dc power is stopped even for a short time, operation becomes impossible. For this reason, when a power source using thyristor inverters is to be uninterruptable, it is always necessary to include a storage battery. *Fig. 10* shows the construction of a uninterruptable power source using thyristor inverters. As can be seen from this figure, when the commercial power lines are normal, ac power is supplied to the load via the commercial power source, a rectifier and the inverter. However, if there should be some fault in the commercial source, the thyristor switch are instantly turned on, and the inverter dc input power is switched to the storage battery side. In this way ac power can be continuously supplied to the load without any stoppages.

In the future, this equipment can be transformed into the uninterruptable type by installing a storage battery, battery charger and thyristor switch on the inverter side. *Fig. 11* shows the results of a power interruption test conducted at the factory using this equipment combined with a storage battery.

VI. CONCLUSION

The stabilized and uninterruptable power source equipment described in this article are intended to be used for computers in particular, as well as instrumentation equipment for the chemical and steel

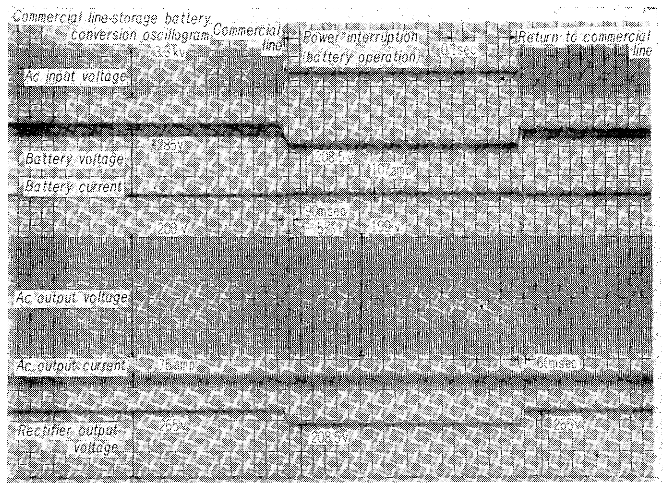


Fig. 11 Characteristics in ac input power interruption

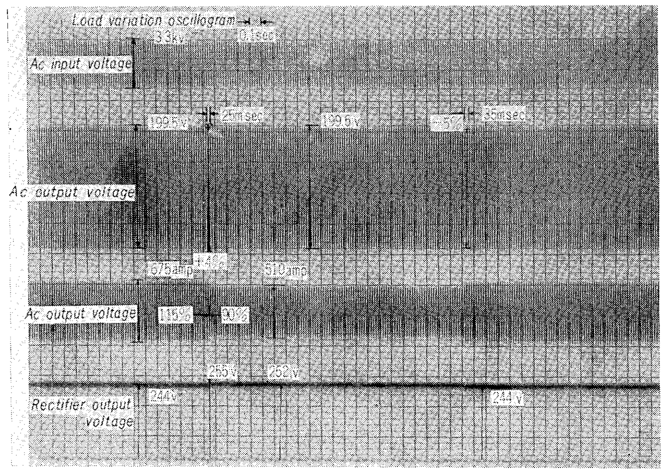


Fig. 12 Transient response of 200 kva CVCF power source equipment

industries and for communication equipment. The needs for such equipment will no doubt gradually increase from now on. As the demands for reliabilty grow, this type of equipment will come to play an even greater role than ever before.

Since Fuji Electric has already manufactured and delivered a lot of this type of power source equipment, this past experience will be used to make even more economical and reliable equipment in the future. The authors wish to sincerely thank all those persons at Fujitsu Ltd. who cooperated in the design and manufacture of this equipment.

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