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TRANSIDYN B SYSTEM CONTROL DEVICES

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I. FOREWORD

With expansion of electronics in the field of control devices for electrical equipment (motors, for instance), thinking concerning control has been and is being revised by leaps and bounds. Progress in semiconductor technology has led to broader application of electronic equipment employing semiconductors. Semiconductor elements in integrated circuits have become smaller and smaller, enabling greater circuit density. In seeking an answer to increasing complexity and scale of control devices, miniaturized, elaborate electronic control devices have appeared. Power semiconductors (thyristors and diodes) offer the advantages of elimination of contacts and moving parts, excellent response, small physical size, and low internal power consumption, as well as maintenance free operation and high reliability, and are being used to greater and greater extents in the field of heavy electrical engineering. In the case of electronic control devices for power applications, better power handling characteristics (in respect to noise, surges, etc., for example) are now required.

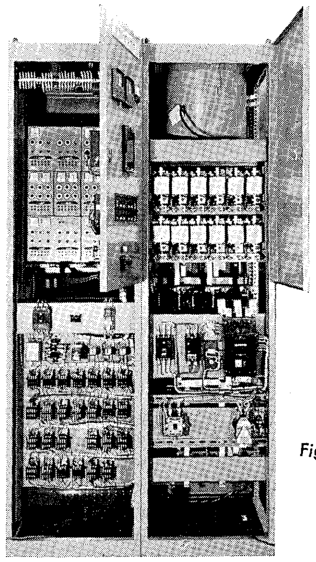

Fig. 1 TRANSIDYN control cubicle

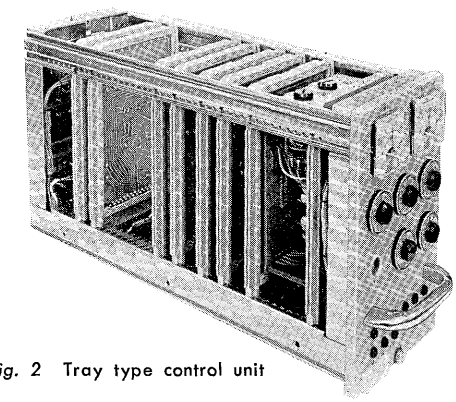

Fig. 2 Tray type control unit

II. CONSTRUCTION AND SYSTEM

TRANSIDYN control devices contain a number of elements offering characteristics which satisfy control objectives.

1. Control Cubicle

To arrange readily, systematically tray and frame control equipments with standardized function and dimensions, the cubicle dimensions have been standardized by using normalized frame materials. So that tray and frame units may be accomodated in a practical manner, the four corner posts of the cubicle have an ample number of mounting holes. *Fig. 1* presents an exterior view of the control cubicle.

2. Tray Units (Type T)

Fig. 2 depicts a tray unit. The configuration is a draw-out type with standardized dimensions. The front panel of units accommodates adjusting parts, a monitoring meter, and check terminals (for checking unit operation), making maintenance quite easy.

An ample number of mounting holes have been included inside tray units, to accomodate standardized printed circuit boards, compact units and block units, all of which may be plugged in according to equipment design. Thus, the final configuration can easily arranged by combining various standardized components.

3. Frame Units (Type F)

Dimensions of frame units are also standardized. The tray system makes use of cubicle depth, while the frame system makes use of cubicle width. Thus,

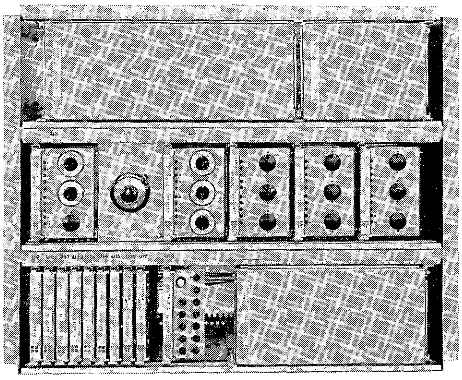

Fig. 3 Frame type control unit

the tray system in advantageous when the cubicle depth is considerable, and the frame system when the cubicle depth is limited. As described for the tray system, a number of standardized units may be combined to give the desired configuration. *Fig. 3* shows a frame unit with three shelves.

4. Units (Type U)

Printed circuit board units are plug-in types with standardized dimensions of 100 mm × 160 mm. The connector has thirty-one terminals. Units may be plugged into tray units, frame units, and block units as required. *Fig. 4* depicts a printed circuit board unit.

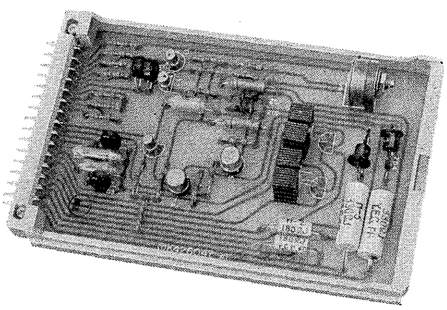

Fig. 4 View of unit

5. Compact Units (Type C)
Small Units (Type S)

Compact units are a miniaturized version of tray units, with the same function. As shown in *Fig. 5*, compact units also have a front panel on which variable controls, a monitoring meter, and check terminals may be installed. The main advantage of compact units lies in the use of integrated circuitry (ICs), reducing space requirements and enabling complex configurations. Here, large and small printed circuit boards are stacked to limit space requirements. *Fig. 6* shows the small printed circuit board unit, with standardized dimensions of 65 × 94 mm and a 15-terminal connector. Compact units may be plugged into tray units, frame units, or block units as required.

6. Block Units (Type B)

As shown in *Fig. 7,* block units are a complex

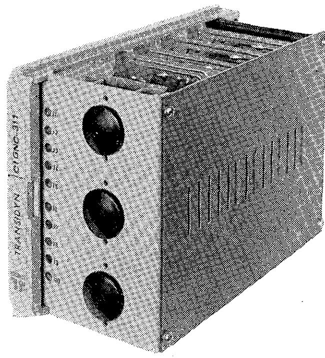

Fig. 5 View of compact unit

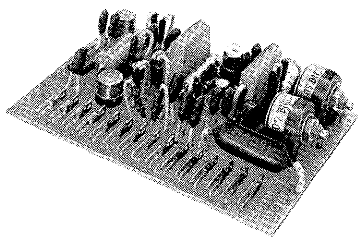

Fig. 6 View of small unit

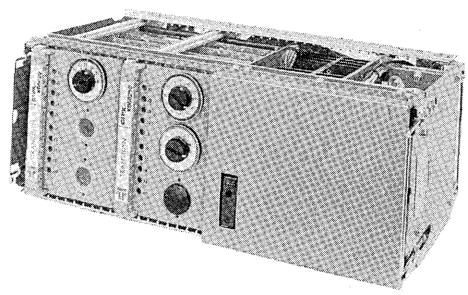

Fig. 7 View of block unit

of ordinary units and compact units. To obtain functional standardization and to arrange for accommodation of heavy components (such as transformers) in tray and frame units, block units have been included. Grooves are located so that optional build-up of units in modular style is possible. Combination is simple.

The arrangement just described is most convenient for electronic equipment installations. From the smallest functional unit to the cubicle, a rational, systematic building block system has been used. Arrangement has been made for plugging various standardized and functionalized units, trays and frames to form a functional system, facilitating design, manufacture, and maintenance. This approach is compatible with that for F-MATIC, companion equipment.

III. COMMON RATINGS

As described, construction and system design for Transidyn control equipment has been standardized. But this is not all: Ratings have also been standardized.

1. Power Supply

1) DC supply voltage

Except in special cases, the DC supply voltage is standardized at ±24 V in a three-wire common line system.

2) AC supply voltage

The AC supply voltage is within +10%/−15% of rated voltage of 200/220 V. Specifications for the DC supply voltage are based on this range of AC supply voltage.

3) AC supply frequency

The AC supply frequency is within +2 Hz/−3 Hz of the rated frequency of 50 or 60 Hz.

2. Control Signal

Except in special cases, the control signal is specified as 10 VDC, in view of transmission characteristics, quality, and easy of handling.

3. Allowable Ambient Temperature

Stable operation is guaranteed over a unit (printed circuit board) ambient temperature range of −20°C/+60°C.

4. Standardization of Terminal Numbers

Regardless of the location, the following terminals are used for listed purposes.

Terminal 1 : DC supply (−24 V)
Terminal 2 : DC supply (+24 V)
Terminal 3 : DC supply (common)
Terminal 31 : Ground (but only when necessary)

IV. STANDARD FUNCTIONAL UNITS

An outline of name, type, and functions for standard functional units appears in *Table 1.* To enable combination of standard functional units for an several purpose, stock includes various input units, feedback units, detector units, relay units, and universal units.

1) DC amplifier units (U4AD, S2AD) and power amplifier units (U4AD(5), U4AD(7P), U4AD(7N))

The DC amplifier unit (U4AD) consists of a differential amplifier stage (grounded emitter connection), current amplifier stage, and output stage (emitter follower connected), and have high gain of voltage current.

The dc amplifier unit (S2AD) is in the shape of a "small unit", with linear integrated circuitry. Dimensions are limited, performance and reliability high.

The power amplifier units (U4AD(5), U4AD(7P), U4AD (7N)) are used following DC amplifier units (U4AD), to raise output current to the desired level. In general, this power amplifier units are used to branch output of operators and controllers, to improve noise characteristics over long transmission runs, to provide for connection to magnetic amplifiers.

2) Limiter units (U3BA, S2BA)

Limiter units are used to start, stop, and limit the output of controllers, operators, etc. Input comes from logic elements, output goes to the base terminal of the transistor in the final stage of a dc amplifier unit.

3) Pulse generator units (U3GP, S3GP)

Pulse generator units are used to provide thyristor gate control. Synchronizing signals are converted to sawtooth waveform with a fixed gradient, comparison to control input effected, and pulses generated. Advantages of this approach are freedom from the effects of waveform distortion and voltage variation in the synchronizing signal, and realization of linear relationship between the input control voltage and control firing angle α.

4) Pulse generator limiter units (U3BG, S2BG)

Pulse generator limiter units are connected ahead of pulse generator units, to amplify the input signal, to limit amplitude of the input signal, α_{min}, γ_{min}, suppress excessive current, and provide for starting and stopping. During normal operation, amplitude of the input signal is limited within the α_{min}, γ_{min} range. If the input signal exceeds established limits, automatic return to a preset value in the rated range is effected. When thyristor current tends to rise to an excessive value, the internal flip-flop operates, allowing the γ_{min} signal to pass as output without relation to the control input. After the problem has been cleared, a reset signal is used to restore the flip-flop to its normal state. In the same manner, a stop command can be used to shift γ_{min} without relation to the input.

5) Pulse amplifier units (U10AP(2), U5AP(1), U5AP(3))

Pulse amplifier units are used to pmplify the output of pulse generator units, to provide gate pulses for firing a number of line thyristors simultaneously through a pulse transmission circuit. As shown in *Fig. 8*, a U10AP(2) is used for each phase, and consists of an interlock circuit, pulse amplifier stage, and output thyristor cutoff circuit. The interlock circuit is a three-input NAND circuit, with one input connected to output of the pulse generating unit. The pulse firing and cutoff commands and emergency pulse cutoff command are applied to the other two inputs to effect circulating current free

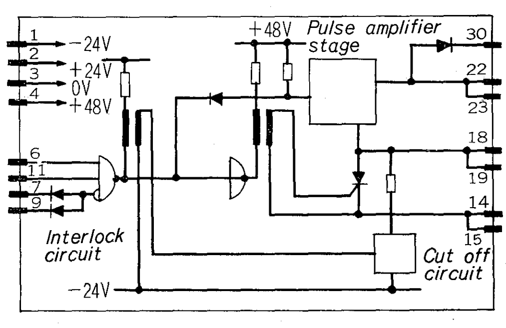

Fig. 8 Circuit of pulse amplifier U10AP (2)

Table 1 **Standard functional units for general applications**

Name	Type	Form	Application	Specifications
DC amplifier unit	U4AD	U	For controls, adjustable operators	Output voltage ±12 V, load resistance more than 670 Ω. Limiting output voltage and holding output voltage to zero possible.
	S2AD	S		Output voltage ±12 V, load resistance more than 1.4 kΩ. Limiting output voltage and holding output voltage to zero possible.
Power amplifier unit	U4AD (5)	U	For amplification of power	Output voltage ±10 V, max. output current 60 mA.
	U4AD (7P) U4AD (7N)	U U		Output voltage ±10 V, max. output current 250 mA.
Limiter unit	U3BA	U	For limiting output voltage, holding output voltage at zero	Zero hold with "0" signal (+24 V), output limiting to 0~±10 V with "1" signal (0 V).
	S2BA	S		Zero hold with "0" signal (+24 V), and aux. signal to stop current controller action −10 V, output limiting to 0~10 V with "1" signal (0 V).
Pulse generator unit	U3GP	U	For generating gate pulses	Control input and control range approx. ±10 V, 90°±90° el, pulse width approx. 30° el double pulse, pulse off with "1" signal (10 V).
	S3GP	S		Control input and control range approx. ±10 V, 90°±90° el, pulse width approx. 120° el.
Pulse generator limiter unit	U3BG	U	For limiting firing angle, blocking over current, shifting firing angle	Limiting of firing angle $\alpha_{min.}$, $\alpha_{max.}$, over current limiting at approx. −8 V, pulse shift with "0" signal (24 V).
	S2BG	S		Limiting of firing angle $\alpha_{min.}$, $\alpha_{max.}$, over current limiting at approx. +8 V, pulse shift with "0" signal (24 V).
Pulse amplifier unit	U10AP (2)	U	For simultaneous firing of a number of line thyristor	Applied thyristor GTL, GTN, KGP, interlock circuit included. Pulse off with "0" signal (+24 V).
	U5AP (1)	U		Applied thyristor GTD,GTE, GTG, GTH, GTL, GTN, KGP, interlock circuit included. Pulse off with "0" signal (+24 V).
	U5AP (3)	U		Applied thyristor GTD; GTE, GTG, GTH, GTL, GTN, KGP, no interlock circuit.
Comparater unit	U3AL	U	For detecting small analog signal	Detected voltage level approx. ±100 mV, max. output current 80 mA.
Logic converter unit	U2LSW	U	For converting a logic signal to an analog signal	With "0" input signal (+24 V), output voltage +12~+6 V; with "1" input signal (0 V), output voltage −12 V~−6 V, max. output current 5 mA.
Signal converter unit	U6LY	U	For converting AC voltage to a logic signal	Input: AC2 00 V. With input voltage present, output "1" signal (0 V), with input voltage absent, output "0" signal (+24 V), max. output current 25 mA.
Voltage stabilizing unit	U4NS (1)	U	For setting application	With input voltage +20 V~+30 V, output voltage +10 V, max. output current 100 mA.
	U4NS (2)	U		With input voltage −20 V~−30 V, output voltage −10 V, max. output current 100 mA.
Motor driven setting unit	B24SAM	B	For setting application	Coasting time: 3.3 s~600 s Rotary slide registor: Single (4~6) ganged and multiturn potentionmeters.
Power supply unit and block unit	U4NG	U	For firing angle regulator	+24 V (stabilized power supply) +24 V, −24 V power supply rectifying circuit.
	B18NSM	B	For motor driven setting unit	Input: AC 200 V, 220 V, 50/60 Hz. Output: AC 100 V/0.3 A×2, +24 V/0.3 A.
	B22NA	B	For controller, operator	Input: AC 200 V, 220 V, 50/60 Hz. Output: +24 V/0.6 A −24 V/0.6 A.
	B22NAL	B	For logic and relay application	Input: AC 200V, 220 V, 50/60 Hz. Output: +24 V/0.6 A, −24 V/0.25 A, +24 V/0.5 A, (for relay application).
	B32NG	B	For controller and firing angle regulator	Input: AC 200 V, 220 V, 50/60 Hz. Output: +24 V/0.4 A, −24 V/0.4 A, +48 V/1 A.
	B39NP	B	For pulse amplifier	Input: AC 200 V, 220 V, 50/60 Hz. Output: +24 V, −24 V, +48 V/5 A.
Check unit	U7WL	U	For logic circuit check	Test: lamp goes out with "1" signal (0 V).

Note: Letters in the Form columu indicate the following.
S: Small unit U: Unit B: Block unit

Table 2 Standard tray control equipment and compact units

	Name	Type	Form	Application and Specifications
Setter	Motor driven setter	T1SAM-14□/9,60	T	Rotary slide resistor: single turn 4 gangs potentiometer. Driving supply self-contained. Coasting time 14□/9: 10~90 s, 14□/60: 60~600 s
Transducer	Isolating transducer	T1TA-21□	T	Input: ±0.5 mA/100%, ±0.5 mA/±10 V/100%, ±1 mA/±10 V/100%, ±2 mA/±10 V/100%, ±5 mA/±10 V/100%, ±10 mA/±10 V/100%. Output: ±10 V/100%.
	Transistor transducer	T1TA-31□	T	Input: ±0.5 V/100%, ±1 V/100%, ±2 V/100%, ±5 V/100%, ±10 V/100%. Output: ±10 V/100%.
Computer	Unit integrator	T1PUJ-11□	T	Used as command generator for acceleration and deceleration of motor. Continuously variable accel. and decel. time up to 0.5~6.0 sec (×1~⅓).
	Unit integrator	T1PUJ-12□	T	Used as command generator for accel. and decel. of motor. Continuously variable accel. and decel. time up to 5~60 s (×1~⅓).
	Unit integrator	C1PUJ	C	Used as command generator for accel. and decel. of motor. Continuously variable accel. and decel. time up to 36~60 s (×1~⅓).
	Regulator to change acceleration and deceleration	T1PDU-21□	T	Used as command generator to change motor accel. and decel. In combination with T1PUJ, accel. and decel. time is twice that of T1PUJ and continuously variable.
	Way regulator	T1PW-11□	T	$V_{out}=\sqrt{kV_{in}}$ (k=20~200).
	Integrator	T1PJ-11□	T	Continuously variable to integrating time of 1.8~6.8 s.
	First lag computer	T1PF-11□	T	Used to offset lag in magnetic flux due to eddy current.
	EMF computer	T1PEM-12□	T	Used to compute back EMF of motor, T_a=6.8~330 ms, armature voltage =rated 100%, variable in 30~100% range, regulation=1~20%, armature current=100~350%.
	Current computer	T1PAC-11□	T	Used to compute armature current.
	Speed computer	T1PAS-11□	T	Summing computer used to determine setting signal for speed of rotation.
	Current limit regulator	T1PBC-11□	T	Used to limit current in relation to motor speed.
	Load balancing regulator	T1PBC-12□	T	Used for load balancing control in two-speed control system.
	Circulating current blocking regulator	T1PBC-13□	T	Used to compute α and γ for circulating current control.
	Tension computer	T1PAT-12□/D	T	Used for tension control from control of armature current. A derivative circuit of line speed for offset computation of accel. and decel. included. Differentiating time of 3~30 s.
	Start-stop regulator	T1LSS-11□	T	Provides start-stop commands for thyristor Leonard control equipment.
	Start-stop regulator	T1LSS-12□/CM	T	Provides start-stop commands for thyristor Leonard control equipment, at the same time provides forward-reverse switching commands in respect to circulating current free control.
	Command regulator	T1LCM-11□/2D	T	Used as forward-reverse switching regulator for circulating current free thyristor Leonard control.
Controller	Current controller	T1CCR-11□	T	Used for motor armature current control by thyristor. Circulating current 0~10%, input +10 V/100%, output ∓10 V/100%. A current detecting circuit included.
	Current controller	T1CCR-11□/2D	T	Used for motor armature current control by thyristor. Circulating current 0~10%, input +10 V/100%, output ∓10 V/100%. Two current detecting circuits included.
	Speed controller	T1CS-11□	T	Used to control speed of rotation and back EMF of motor. Input ∓10 V/100%, output ±10 V/100%. Tachogenerator detecting circuit DC 40~200 V included.
	Speed controller with current controller	T1CSR-12□/C	T	Used for three-phase pure bridge circulating current free thyristor Leonard control. Input ∓10 V/100%, output ∓10 V/100%. Tachogenerator detecting circuit DC 40~200 V and two current detecting circuits included.
	Speed controller with current controller	C1CSR-12□/C	C	Used for non-reversible speed control of DC motor under thyristor Leonard control. Input ∓10 V/100%, output ∓10 V/100%.
	Speed controller with current controller	T1CSG-12□/C	T	Used for speed control of DC motor under Ward-Leonard control. Input ∓10 V/100%, output ∓10 V/100%. Tachogenerator detecting circuit DC 40~200 V included.
	Field controller	T1CF-11□	T	Used for control of motor field current or back EMF of motor. Input +10 V/100%, output ∓10 V/100%. A current detecting circuit included.
	Acceleration and deceleration controller	T1CDS-12□	T	Used for torque control of DC motor under thyristor Leonard control. Input ∓10 V/100%, output ±10 V/100%. Derivative circuit of speed of rotation included.
	Tension controller	T1CT-11□	T	Used for high accuracy tension control. Input ±10V/100%, output ∓10V/100%.
	Loop controller	T1CL-11□	T	Used for loop length and height control. Input ±10 V/100%, output ∓10V/100%.
Firing angle regulator	Firing angle regulator	T2GNC-61□	T	6 phase, L.N.P. type thyristor firing, D.E.G.H. type thyristor firing. Power supply for pulse transmission circuit included.
	Firing angle regulator	T2GNC-61□/1A	T	6 phase, simultaneous firing of up to three L.N.P. type thyristors.
	Firing angle regulator	T2GNC-61□/2A	T	6 phase, circulating current free control. Simultaneous firing of up to three L.N.P. type thyristors. Output 12 phases.
	Firing angle regulator	C1GNC-31□	C	3 phase, firing of D.E.G.H.L.N. type thyristors. 6 phase firing with C1GNC-31□+C1GNC-31□/1.
Pulse amplifier	Pulse amplifier	T1APR-31□	T	For simultaneous firing of a number of L.N.P. type thyristors.
Power amplifier power supply	Pulse amplifier power supply	T1NP-11□	T	Power supply for T1APR-31□×2 to fire simultaneously four or less L.N.P. type thyristors. Output ±24 V, +48 V.
	Pulse amplifier power supply	T2NP-12□	T	Power supply for T1APR-31□×2 to fire simultaneously five or more L.N.P. type thyristors. Output ±24 V, +48 V.
DC power supply	DC power supply	T1NAL-11□	T	Input: AC 200 V/220 V/240 V, 1 ϕ Output for analog: ±24 V (0.6 A), for logic: +24 V (0.6 A), −24 V (0.25 A), for relay: +24 V (0.5 A).
	DC power supply	T1NA-11□/1	T	Input: AC 200 V/220 V/240 V, 1 ϕ Output: ±24 V (0.6 A), ±10 V (0.1 A) with constant voltage.
	Hall DC power supply	T1NAH-11□	T	Input: AC 200 V/220 V/240 V, 3 ϕ Output: (0.6~0.9 A)×2 circuits.
	Drive for motor driven setter	T1NSM-11□/NA	T	One B18 NSM block unit and one B22 NA included.

Note: Letters in the FORM column indicate C: compact unit
T: tray unit
□: the design number is shown in brackets

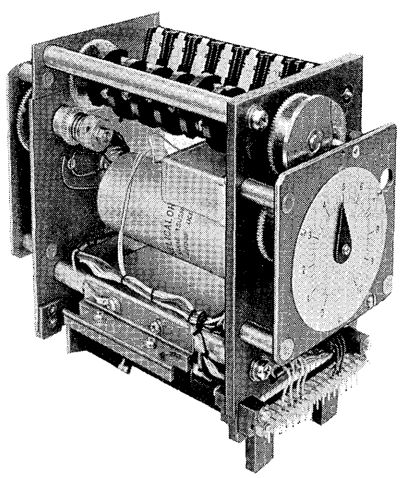

Fig. 9 Motor driven setting unit B24SAM

thyristor Leonard control. When a firing pulse arrives from the pulse generating unit, the output thyristor and transistor conduct at the same time. The gate pulse signal passes through the pulse transmission circuit of the load, to the gate of the line thyristor. When an off command appears at the input, the output transistor stops conducting. A voltage of the opposite polarity is applied to the output thyristor from the cut-off circuit, and this thyristor stops conducting. Then the gate current of the line thyristor is interrupted. Unit U5AP (1) one is used for three phases, and consists of an interlock circuit and pulse amplifier stage. A high-capacity transistor is used in the pulse amplifier stage, in order to provide for simultaneous firing of a number of line thyristors. The unit U5AP(3) is connected directly to the pulse generating unit, to amplify the firing pulse current.

6) Motor driven setting unit (B24SAM)

The motor driven setting unit is used to set the reference value for an automatic control system from a remote point, to effect a time relationship for the rate of rise or fall of the reference value, or to store control information. In this unit, a two-phase servomotor is used to drive a rotary potentiometer (sealed type which dust and gas cannot enter). The two-phase potentiometer is driven by a block unit (B18NSM) (motor driven setting unit power supply). To provide mechanical protection, a sliding mechanism is used. This arrangement provides a high degree of safety. Refer to *Fig. 9* for an exterior view.

V. STANDARD FUNCTIONAL EQUIPMENTS

Ordinary control equipment possesses setting, detecting, and operating functions. Combinations of standard functional units were described under "IV." Here, standard functional equipments will be described.

1. Controller

The controller consists of a dc amplifier unit (U4AD) witn high gain and stability, and input unit for determining the difference between reference and actual values, a feedback unit for effecting lead and lag compensation (PID), and a limiter unit (U3BA) for limiting the output signal of the controller, and must have high static control accuracy and good dynamic control characteristics. *Fig. 10* shows the basic circuit of the controller.

1) Armature current controller (T1CCR-11□, T1CCR-11□/2D)

These controllers are suited to control systems for the armature current of DC motors controlled by thyristors. With PI characteristics, the output signal of the controller is used to establish the thyristor firing angle. A negative output signal provides a firing angle reference in the α range, a positive output signal in the γ range.

2) Speed controller (T1CS-11□)

This cotroller is suited to control systems in which the speed of rotation and back emf of a DC motor must be controlled, by forming the armature current control system (without or with circulating current) with a armature current controller (T1CCR) into a minor loop. With PI characteristics, the output signal is altered to provide a reference signal for the armature current controller. To start, stop, and limit output of this controller, a " 1 " or " 0 " signal is applied to the limiter unit (U3BA). The output limit is set by means of an internal potentiometer. The detector unit (U4DS) accepts DC voltage (40–200 V) from the generator used to detect motor

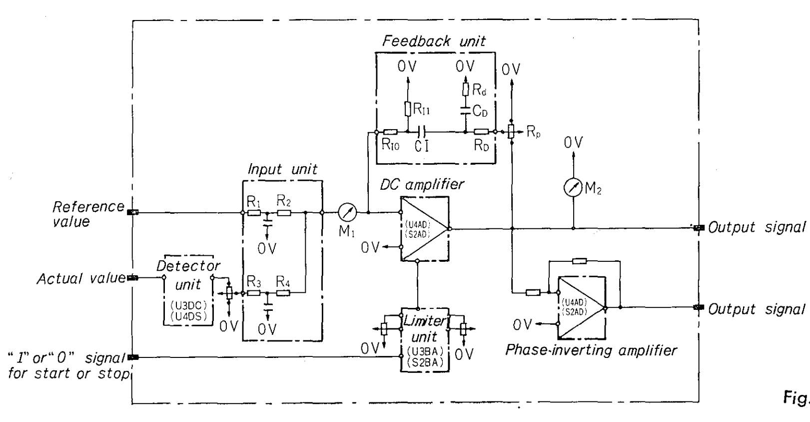

Fig. 10 Circuit of controller

speed, after which a potentiometer is used to drop it to 10 V.

3) Speed-current controller (C1CSR)

This controller (in the form of a compact unit) is suited to speed control and back emf control of DC motors, to be controled by thyristors. One compact unit accommodates speed and current control function components, both of which have PI characteristics for fixed integrating time. Starting and stopping are effected by " 1 " and " 0 " signals. In the event of stopping, output of the speed control portion is held zero and output of the current control portion is made γ_{min}. The output limit (current limiting reference value) of the speed control portion can be varied continuously in the $0 \sim 10$ V range by means of an internal potentiometer. The output limit for the current control component is established with a signal from the firing angle regulator (used to fire the thyristors).

2. Computer

In making the automatic control system more complex and obtaining a high level of control, a satisfactory state of control cannot be realized with the PID controller alone. So various computers are required.

1) Unit integrator (C1PUJ)

The unit integrator has computing and integrating functions. Without relation to the level of the input signal, the output variation has a fixed time gradient. Eventually, the output signal level reaches the input signal level. To allow the output signal to become zero, a semiconductor analog switch is used. When this unit integrator is used for motor acceleration and deceleration control, a reference signal (output signal of this unit integrator) must be supplied to the speed controller. Linear integrated circuitry (ICs) is used in this integrator, to limit drift, provide high reliability, and make dimensions small.

2) Start-stop regulator (T1LSS-11□)

This regulator is a control device for the TRANSI-

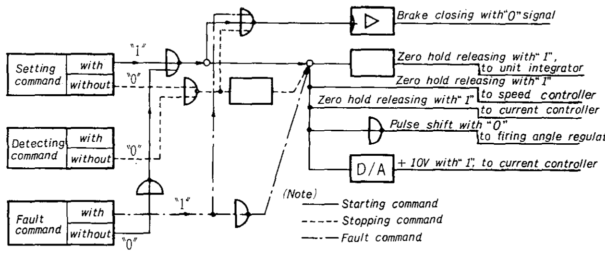

Fig. 11 **Block diagram of start-stop regulator T1LSS**

DYN system, and establishes conditions for sending a zero holding command (forcing the output signal to 0 V) and auxiliary setting command to controllers and computers at starting, stopping, and fault times, sending a pulse shift command (unrelated shift of phase controlled firing pulse to γ_{min} position) to the firing angle regulator, and a control command to the brake. Operating principles of this regulator are illustrated in *Fig. 11*. In the case of circulating current free thyristor Leonard control, this regulator and the command regulator (described below) are combined to provide command signals.

Note: The start-stop regulator (T1LSS-12□/CM) combines functions of the regulator just described and the one described below, as a special unit for circulating current free control.

3) Command regulator (T1LCM-11□)

This regulator is used for circulating current free thyristor Leonard control, used as a command regulator for current switching of forward and reverse transducers connected in inverse parallel. Operating principles are illustrated in *Fig. 12*. The direction of torque is detected, the pulse amplifier on the corresponding side activated, and line thyristors fired, allowing current to flow. When the reverse command is received, the direction of torque reverses. At this time, the pulse signal is shifted to γ_{min} and the current is throttled. The zero current state is detected. Gates of line thyristors conducting up to this point are cut off. After a fixed length of time,

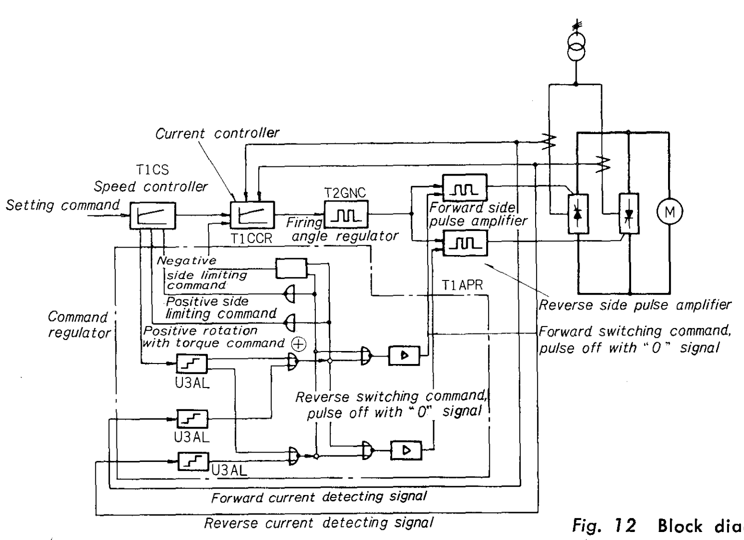

Fig. 12 **Block diagram of command regulator T1LCM**

line thyristors on the side corresponding to the present torque signal fire, causing current to flow in a new direction.

3. Transducer

When the control signal level is low or the control signal must be isolated, transducers are used. Transducers have a function to convert control signals to TRANSIDYN unified signals.

4. Setter

Motor driven setter (T1SAM-14□/9, 14□/60)

The motor driven setter consists of a motor driven setter block unit (B24SAM) and power supply unit (B18NSM) in a single tray. Usually four-section potentiometer is used.

5. Firing Angle Regulator

The firing angle regulator converts the output signal from the controller to a pulse signal with phase adjusted in proportion to the output signal, to provide a signal for thyristor gate control. A block diagram is shown in *Fig. 13.* This regulator:

(1) Makes use of the zero synchronizing method. In principle, there can be no effect from voltage variation in the synchronizing signal or waveform distortion.

(2) Converts the synchronizing signal into a sawtooth signal with fixed gradient. The resultant signal and the input signal are compared. Therefore, the input signal and control firing angle are linear. By limiting the input signal, the control firing angle can be limited.

1) The C1GNC-31□ is contained in a compact unit, and used as a thyristor converter of the three-phase hybrid bridge type. By using two units, a three-phase pure bridge can be formed. Maximum pulse width is 120°. One thyristor per arm is fired.

2) The T2GNC-61□ is used to fire thyristors connected in a three-phase pure bridge, and is suited to a high-capacity reversible converter. This regulator has a circuit which instantaneously interrupts the output pulse signal in the event of abnormal control power. The thyristor converter is well protected. A transistor pulse amplifier (USAP(1) or USAP(3)) can be included, allowing a maximum of three thyristors per arm to be fired. In order to fire four or more thyristors simultaneously, the pulse amplifier described under "6" may be connected.

6. Pulse Amplifier

1) Pulse amplifier (T1APR-31□)

This pulse amplifier is used to fire simultaneously a number of thyristors (applicable thyristors types: GTL, GTN, KGP) connected in series or parallel with the line. It is connected following the firing angle regulator. Phase controlled pulse output is (current) amplified, and passes to the line thyristor gates through the pulse transmission circuit, to provide gate firing current. Pulse amplifier (T1APR-31□) is contained in a tray, with provision for three-phase application. There is a pulse amplifier unit (U10AP(2)) for each phase.

VI. CONTROL DEVICES

The analog control field is found throughout industry, and is very broad. TRANSIDYN B control equipment has a very important position in the world of power equipment control. Control may be broken down into that for dc motors, ac motors, and power equipment. Let's take a look at make-up and utilization of standard functional equipments (described in "V") in an actual, standard control system.

1. DC Motor Control

To vary the speed of a DC motor, the armature voltage or the field current may be changed. The direction of rotation in the DC motor may be reversed by changing polarity of these. The method of control in the case of reversible operation depends on the

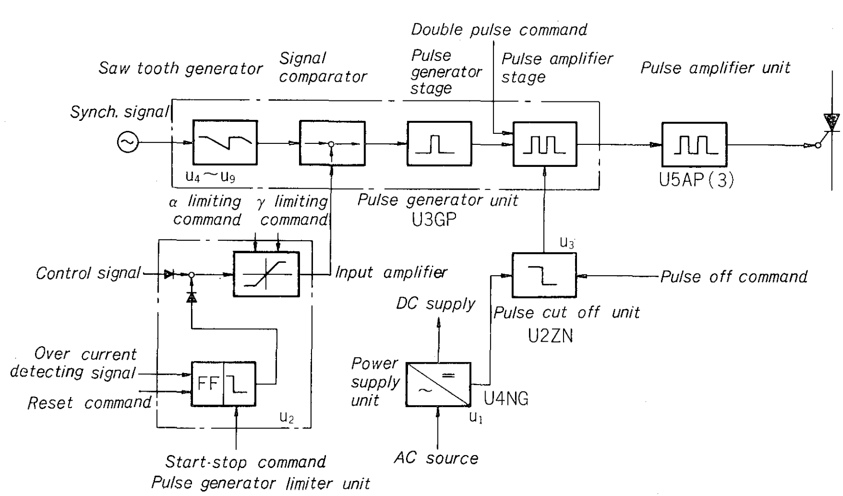

Fig. 13 **Block diagrm of firing angle regulator T2GNC-61□/1A**

frequence and responce of switching between forward and reverse, motor capacity, and costs. Ordinarily, when the switching frequence and responce are low, a switch is used in the armature or field circuit. When the switching frequence is high, on the other hand, circulating current control, circulating current free control, or reversible field control is used. In the case of high capacity motors, field capacity is usually a few per cent of armature capacity, and reversible field control is used from the standpoint of converter capacity and cost.

1) Circulating current reversible thyristor Leonard control.

Thyristors permit current flow in one direction only. As an example of using thyristors to reverse DC motor operation by controlling polarity of power applied, two thyristor converters may be installed in a cross-connection system. In this case, circulating current flows between the converters, giving rise to smooth switching without delay between forward and reverse operation. Accelerating and braking current is supplied in this manner.

2) Circulating current free reversible thyristor Leonard control.

In the case of circulating current reversible thyristor Leonard control, acceleration, braking, and forward-reverse switching are smooth. But there are disadvantages: Transformer and rectifier capacity is considerable. As power losses from circulating current would be high, a DC reactor must be installed to suppress circulating current. With circulating current free control, two thyristor converters are connected in inverse parallel. As only one side is operated at a time, the problem mentioned above is eliminated. In order to carry out operation by selecting one of the thyristor converters in accordance with required polarity of armature current in the motor, a certain amount of idle time arises from logic decision at the time of switching. *Fig. 14* is a block diagram of circulating current free reversible thyristor Leonard control system. In switching thyristor converters, commutation failure must not occur, the converters must not both conduct at the same time, and idle switching time must be held to a low value. Logic decision and protection are handled by the command regulator. Actual contacts are not used.

3) Reversible thyristor Leonard control for switching armature circuit

With this system, only one thyristor converter is required in the armature circuit, making installation costs low. This approach is applicable when frequency of the reversing operation is relatively low. As in the case of circulating current free control, reverse torque is detected by the command regulator, current in the armature circuit is brought to zero, and the line magnetic contactor is switched, restoring operation to normal.

4) Reversible thyristor Leonard control with reversible field circuit

One thyristor converter is installed in the armature circuit of the DC motor, and two converters in the field circuit. When direction of the output torque is to be switched, polarity of the motor field current is inverted. Armature switching is not used. In comparing this arrangement to the one in which separate groups of thyristors are employed to switch the armature circuit, switching response time for torque change and deceleration requiring field switching is delayed by the amount of time required for field control loop. *Fig. 15* is a block diagram of speed control by means of reversible thyristor Leonard control with reversible field circuit. This system consists of speed control with a minor loop for armature current, and a field control loop for reversing the field.

In accordance with polarity of torque to be required and direction of rotation, the torque command from the speed controller is provided to the field setting computer to switch the field circuit. The correct field setting value is then applied to the field current

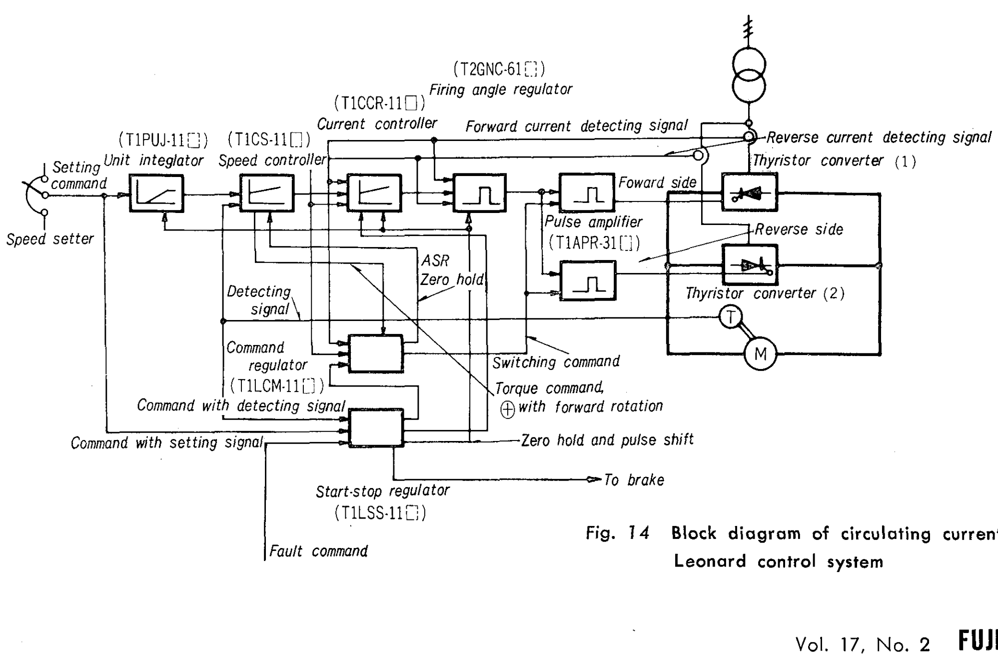

Fig. 14 Block diagram of circulating current-free thyristor Leonard control system

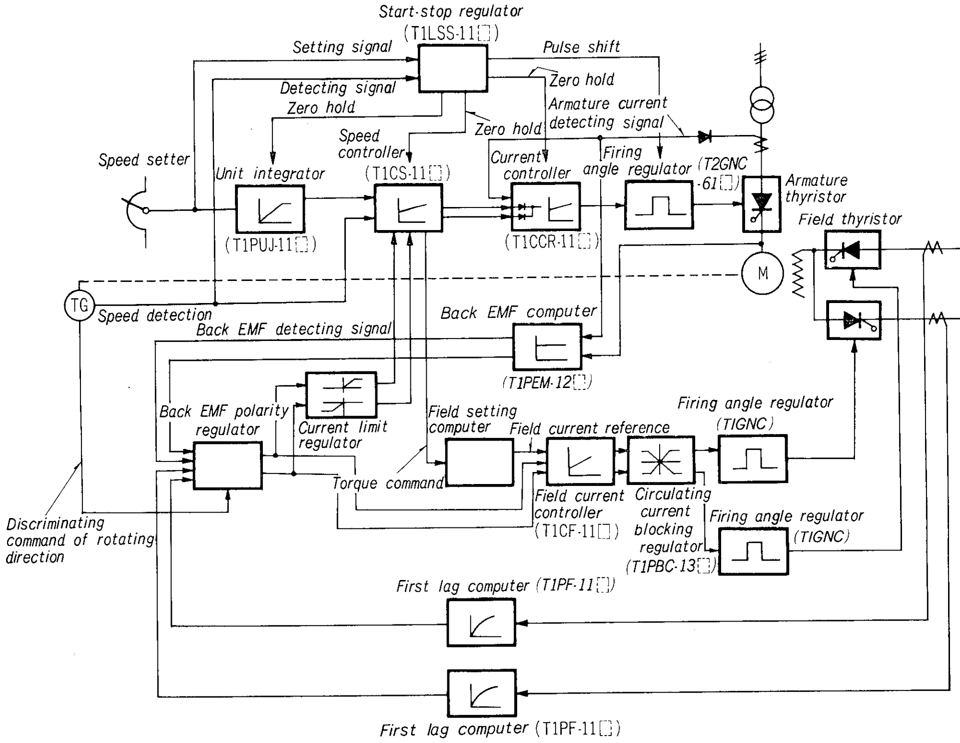

Fig. 15 **Block diagram of reversible thyristor Leonard with reversible field circuit**

controller. The back emf signal must be reversed when the direction of motor rotation is reversed, to keep feedback from going positive. Switching is carried out by the back emf polarity regulator. When the torque command is reversed, output of the speed controller drops to 0 V through action of the current limit regulator. Until the polarity of field current reverses, the speed controller output remains at 0 V (zero control of armature current at this time). After reversal, current controlled by the current limit regulator agains flows in the armature and gradually rises. When current corresponding to the required torque is flowing in the armature, the field reversing operation is complete.

5) Reversible thyristor Leonard control with field switching circuit

In the case of field switching, a rectifier and magnetic contactor for field switching are used in the field circuit. Polarity of the required torque is detected by the command regulator, armature current is driven to zero, and field current is switched by means of the magnetic contactor. A new operating state results. With this system, idle time is more than that for the field reversing system, but the cost is less as a field circuit converter and control equipment are not required. This system is suited to small and medium DC motors when the reversing frequency is low and switching time is not important.

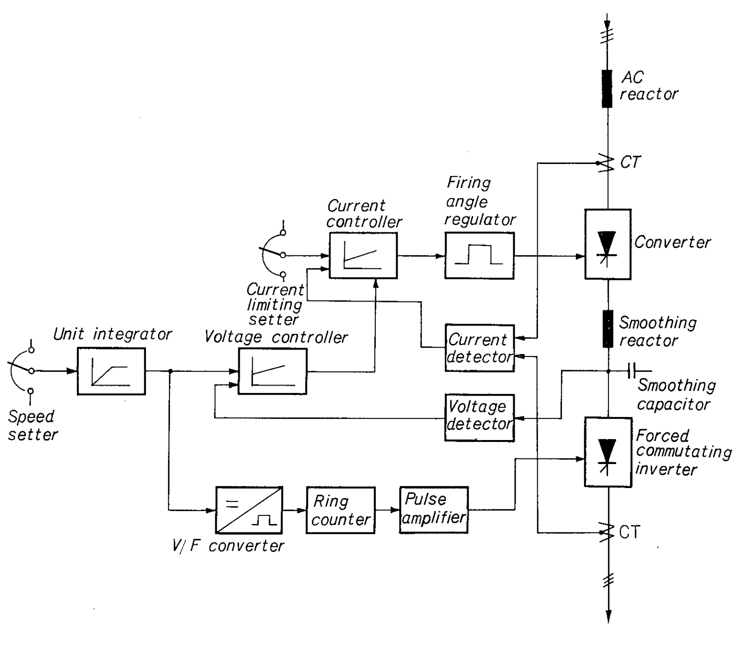

Fig. 16 **Block diagram of thyristor inverter with variable frequency and voltage**

2. AC Motor Control

As a method of ac motor speed control, the input frequency may be varied, or secondary resistance (in the case of induction motors) may be varied. Here, a thyristor inverter with variable frequency and valtage, brushless commutator motor control device, static Scherbius control device, and thyristor-type electrode regulating device will be described.

Control device in these categories requires little maintenance and is not readily affected by corrosion. Brushless com-

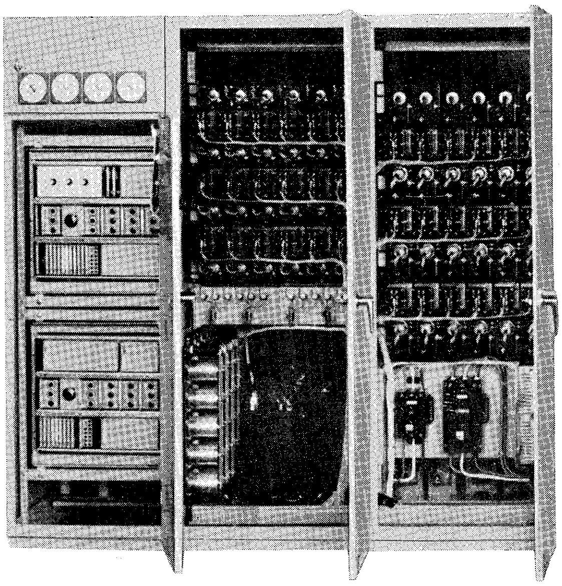

Fig. 17 Thyristor inverter control device

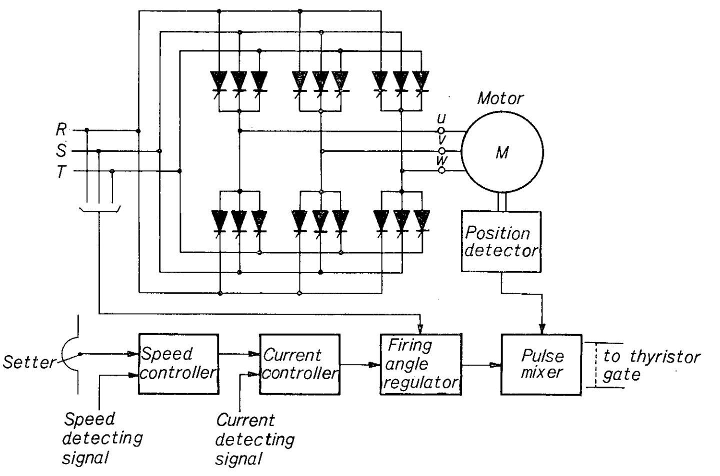

Fig. 18 Block diagram of AC thyristor motor

mutator AC motor control device, while resembling a DC motor, offers many advantages, and expansion of demands in this area may be expected.

1) Thyristor inverter with variable frequency and voltage

When the frequency of a frequency inverter for motor control is changed, the voltage must be changed by a proportional amount, in order to maintain internal magnetic flux at a fixed level. In the example shown in *Fig. 16*, the control circuit consists of a voltage control circuit with closed loop for phase control of thyristor converter, an open loop control circuit for adjusting the frequency of the forced commutation type thyristor inverter, and a speed setting section. The setting signal is applied to both control circuits.

In textile plants, the output frequency must be highly stable. Exacting requirements are easily satisfied with Fuji voltage-frequency converters using the constant current charging type multivibrator.

Fig. 17 shows a view of control cubicles with frame type construction.

2) Brushless commutator motor control device (thyristor motor)

This arrangement has control characteristics equalling those of the DC motor. And yet commutator and brushes are unnecessary. The variable speed brushless motor was made possible by appearance of the thyristor.

Fig. 18 shows control equipment consisting of line circuitry with cycloconverter, motor, and rotor position detectors, and consisting of control equipments with speed controller, current controller, firing angle regulator, and pulse mixer. In accordance with the input differential of the speed controller, the firing angle regulator determines control angle α of the supply voltage. Control lead angle γ of the motor voltage is determined by signals from the position

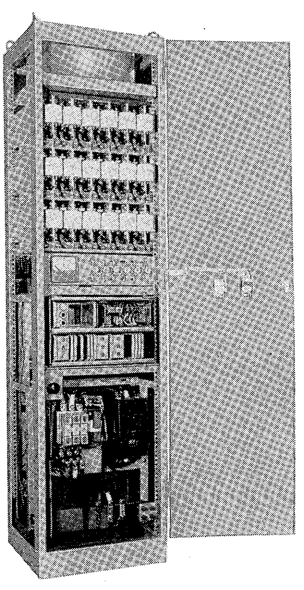

Fig. 19 AC thyristor motor control device

detectors. These signals acting on a logic and circuit form the thyristor gate signal. Since suitable torque is developed in accordance with the rotor position, the usual problems of synchronous machines—asynchronous and random operation—do not exist. *Fig. 19* shows an exterior view of the control equipment.

3) Thyristor-type electrode regulating device

Fig. 20 is a block diagram of this approach. Electrode voltage and current are used as input signals for an arc current controller. Output is used as a speed command for an electrode up-down motor, and enters the speed controller. Output from the speed controller becomes input for the dead zone computer. There is a considerable difference between minimum torque required to keep the electrode from dropping of its own weight and minimum torque required to raise the electrode. Therefore, if the dead zone computer were to supply a current command corresponding to the midpoint between these values

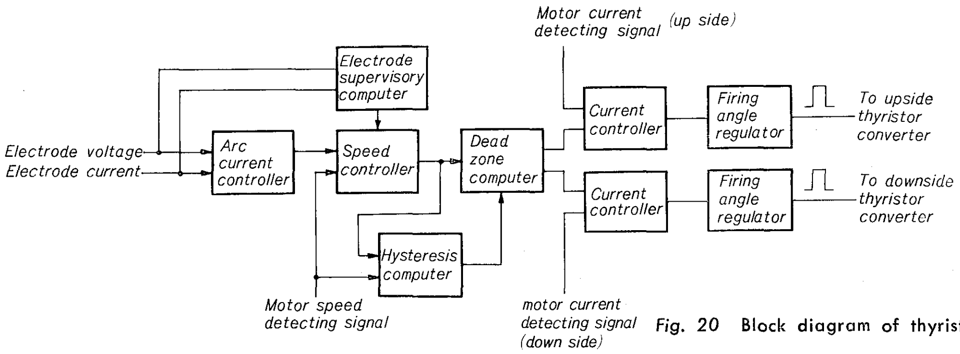

Fig. 20 Block diagram of thyristor-type electrode regulating device

for a long period of time, motor temperature would rise rapidly. To prevent this condition, output of the speed controller is blocked at the dead zone computer by the hysteresis computer. After the motor operates, however, this action is inhibited.

4) Static Scherbius control device of induction motor

An example of applying voltage of the opposite polarity to the rotor of a polyphase motor to effect control is the Scherbius system. A portion of power applied to the primary side of the motor passes through the inverter and is returned to the source. As rectifier and inverter losses are low, overall equipment efficiency is quite high.

3. Power Control Device

With the advent of greater industrial activity, power demands have grown. Generator capacity has become very large and facilities have been rationalized. Control equipment has moved from mechanical to electrical to electronic types in turn. The electric governor, automatic voltage control, and automatic voltage and var power control have already been standardized. In conjunction with advancement of industrial data equipment, the use of static no-break power equipment to supply on-line computers has become necessary.

1) Electric governor

The governor for diesel engines, hydroturbines, steam turbines, and gas turbines has been changed from a mechanical type to an electrical type using electronic components. The speed of rotation of a turbine can now be accurately checked with a system consisting of a digital pick-up, crystal oscillator, and digital-analog converter, a digital detector. The detecting circuit can be split into two parts, with both monitored. In the event of failure on the part of one, automatic switching to the other (standby) maintains service. As a valve opening control loop is used at the inside for speed control, the valve opening (generator output) can be limited by limiting output of the speed controller. This means that starting and load limiting operations may be readily accomplished.

2) Automatic voltage control for synchronous generator

Control equipment is standardized in eight types for steam power, water power, excitation system, and excitation capacity. *Fig. 21* is a control block diagram for a compound thyristor exciter.

The generator voltage appears as a DC signal, with a voltage detector consisting of positive phase filter and responsible filter. This signal is compared to the voltage setter signal, and controlled. To provide automatic power factor control and automatic var power control, the output signal from a var detector is applied. Due to impedance of current and potential transformers in the exciter and to inherent characteristics of thyristor circuitry, the thyristor input

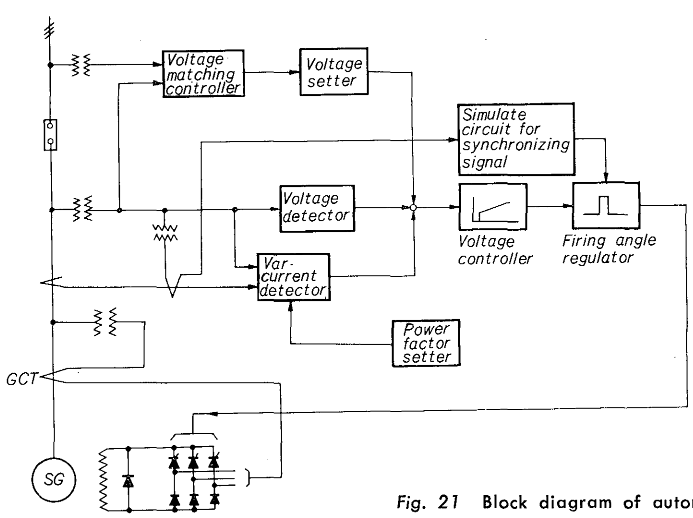

Fig. 21 Block diagram of automatic voltage control device

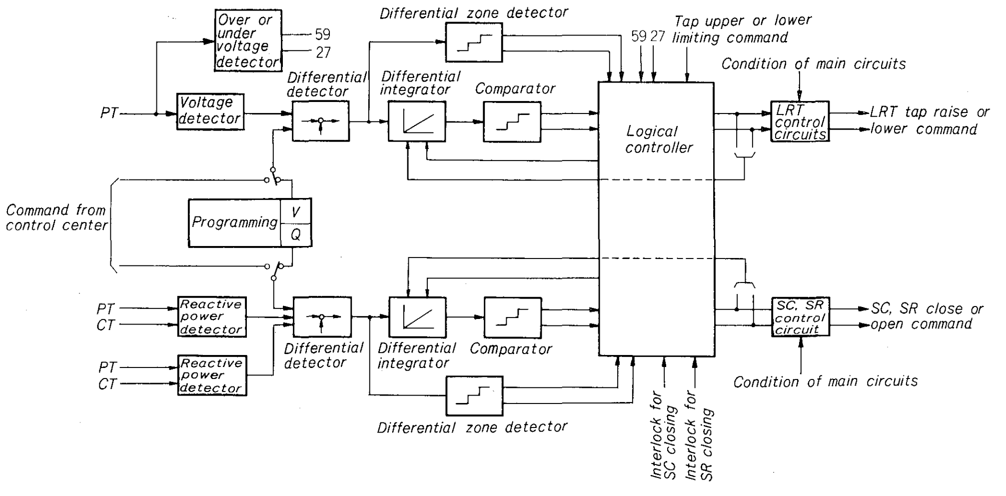

Fig. 22 **Block diagram of automatic voltage and var power control**

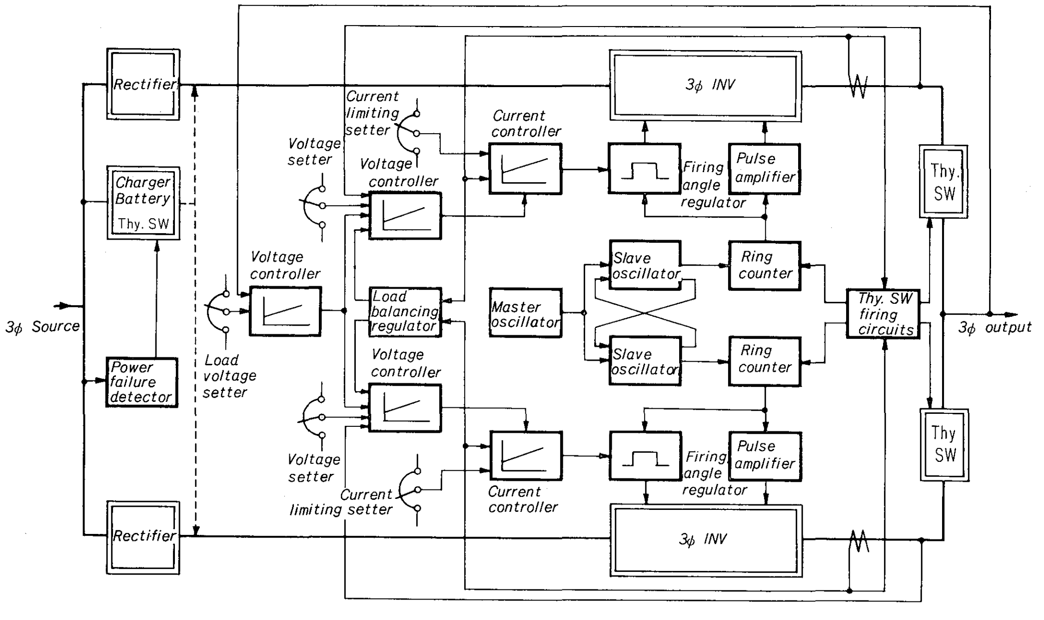

Fig. 23 **Block diagram of CVCF power supply equipment**

waveform contains harmonics, and distoration becomes large. For this reason, the synchronizing signal for the firing angle regulator is taken from a simulate circuit having separate current and potential transformers. This approach eliminates distortion and interference.

When precise automatic var power control and automatic power factor control are required, accessory equipment can be added.

3) Automatic voltage and var power control

Power substations must control voltage and var power, a task accomplished by rotary condensers, on-load tap changers (LRT), power condensers (SC), and branching reactors (SR). *Fig. 22* is a block diagram showing power substation voltage and var power control.

For var detection, a converter for time shared multiplier circuits is used. Lineal integrated circuitry (ICs) is used for differential detection and difference integrating circuits, making dimensions very small and reliability very high. To prevent error due to noise during operation, a signal checking circuit is used. After a raise or lower command (or a close or open command), the signal is returned to the preceding stage for rechecking, after which it is fed to the exterior. This arrangement provides double protection.

4) Static no-break power supply system

No-break power equipment with thyristors and inverters is widely used to supply computers, communication equipment, and industrial instruments.

As shown in *Fig. 23,* the control circuit consists of a freqnency reference circuit (including master oscillator) and output voltage control loop, thyristor firing circuit, and power failure detector for switching the load to battery power. So that failure of an unit will not affect the supply of power, redundancy is used throughout. A load balancing regulator is included for balancing loads during parallel operation.