UDC 654. 94

URD TYPE REMOTE SUPERVISORY CONTROL EQUIPMENT

Masahiko Sasamoto
Control Technique Center

I. INTRODUCTION

On the basis of cooperative research with Fujitsu, Fuji Electric for the first time in industry started test production of transistor type remote supervisory control equipment with many excellent features in April, 1958 to replace the former electromagnetic relay system. Since the first of this equipment went into actual operation in March, 1959, good results have been obtained with many sets of the equipment delivered to power receiving stations, substations, various types of industrial plants, waterworks, railroad and road traffic control centers, etc. During this period, many improvements have been made due to the introduction of new techniques. These improvements have covered circuit construction, signal systems, panel construction, etc. For several years, the UR type equipment has been manufactured as a standard series and many units have been delivered. However, the publication of the study report by the Society of Electrical Co-operative Research caused many manufacturers to adopt the specifications given in the report. On the basis of these specifications, the former UR type underwent partial improvement and the URD type (TC-100 URD, TC-60 URD) was born. Since 1969 when the first set of the URD type was delivered, almost 100 sets have been delivered and satisfactory results have been obtained.

II. OUTLINE OF EQUIPMENT

1. Equipment capacity

The remote supervisory control equipment generally consists of a master station and a remote station. The equipment is capable of selective control of any devices in the remote station from the master station, as well as display in the master station of the conditions of devices in the remote station. The general capabilities of the equipment are :

(1) ON and OFF control from the master station of devices in the remote station (breakers, disconnecting switches, etc.) can be performed optionally for a maximum of 100 items (100 positions : TC-100 URD type) or 60 items (60 positions : TC-60 URD type).
(2) A maximum of 100 items or 60 items concerning the condition of devices in the remote station, faults, etc. are normally displayed in the master station. At the time of automatic condition changes, warnings are given automatically by flickering, bells or buzzers.
(3) For each control position, three modes are possible : ON, OFF and spare. The ON and OFF command is given in one second by contacts with 110 V 5 A DC switching capacity.
(4) For one display position, the inverse display is given. For example, in the case of a circuit breaker, the display is closed (R), open (G) or whether or not there is a fault.
(5) The equipment test functions are performed directly by a indication inversion test.
(6) When there is a delay in equipment display or control, or when there is an abnormality in the transmission routes, an alarm is given immediately in the master station.
(7) It is possible to indicate selection measurements when telemetering is attached simply by means of selective operation. Indications is also possible when only control operation of the selection measurements is performed.

2. Standard Specifications

(1) Iron panel
Height: 2,350 mm, width: 600 mm, depth: approx. 300 mm
(2) Paint color
Munsel 7.5 BG 6/1.5, $G_s=50$
(3) Power supply
110 V DC (range of variation : 90 to 140 V)
(110 V/220 V AC power supply panel is also possible)
(4) No. of positions
Control and display maximum of 100 positions (TC-100 URD) or 60 positions (TC-60 URD)
(5) Signal system
Long and short pulse system,
long pulse width : 10 ms (200 bauds)

short pulse width: 5 ms (200 bauds)

(6) Signaling speed

200 bauds for both control and display

(7) Modulation system

FS modulation system with ±100 Hz frequency shift for both control and display

(8) Frequency (FS modulation center frequency)

Control: 1,200 Hz, display: 1,600 Hz

(9) Transmission line

Four exclusive lines (two also possible)

(10) Code checking system

Control: repetitive transmission check, total pulse check and constant total pulse system

Display: repetitive transmission check, total pulse check and parity cheek

(11) Transmission time

Selection: approx. 3 seconds

Control: approx. 0.5 seconds

Display: sampling time of 3.2 to 4.3 seconds

(12) Ambient conditions

Temperature: −10°C to +45°C

Humidity: 30 to 90%

(13) Withstand voltage

Withstand voltage between all external terminals and ground: AC 2,000 V for one minute

(14) Parts used

Logic circuits use silicon transistors and diodes, the input/output circuits for connection to the power equipment use wire spring relays.

Fig. 1 shows an outerview of the URD equipment.

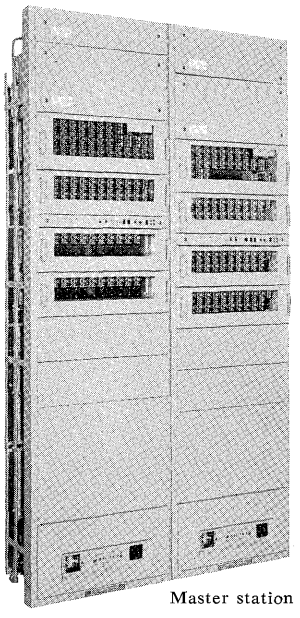


Fig. 1 URD type remote supervisory control equipment

III. CODES

The word "position" is used in remote supervisory control equipment but actually one position can perform a control operation of ON/OFF and its response display. Therefore, the capacity of the equipment is decided by the number of positions that are provided. In remote supervisory control equipment, the transmission lines which connect the master and remote stations must be as few as possible (two or four), and the transmitted data must be classified into positions as well as control and display contents. It is also necessary to use codes so that the data can be transmitted economically and reliably. A pulse code system is generally used in this case. However, since the pulse voltage and width are small in transistor circuits, the pulses can not be transmitted directly in transmission lines. Therefore, in transistorized equipment, the DC level pulse code is converted into frequency signal through FS modulation and frequency signal is sent through an insulation transformer to the transmission line. For the FS modulation subcarrier, a wave of voice frequency is used, and center frequencies of 1,600 Hz

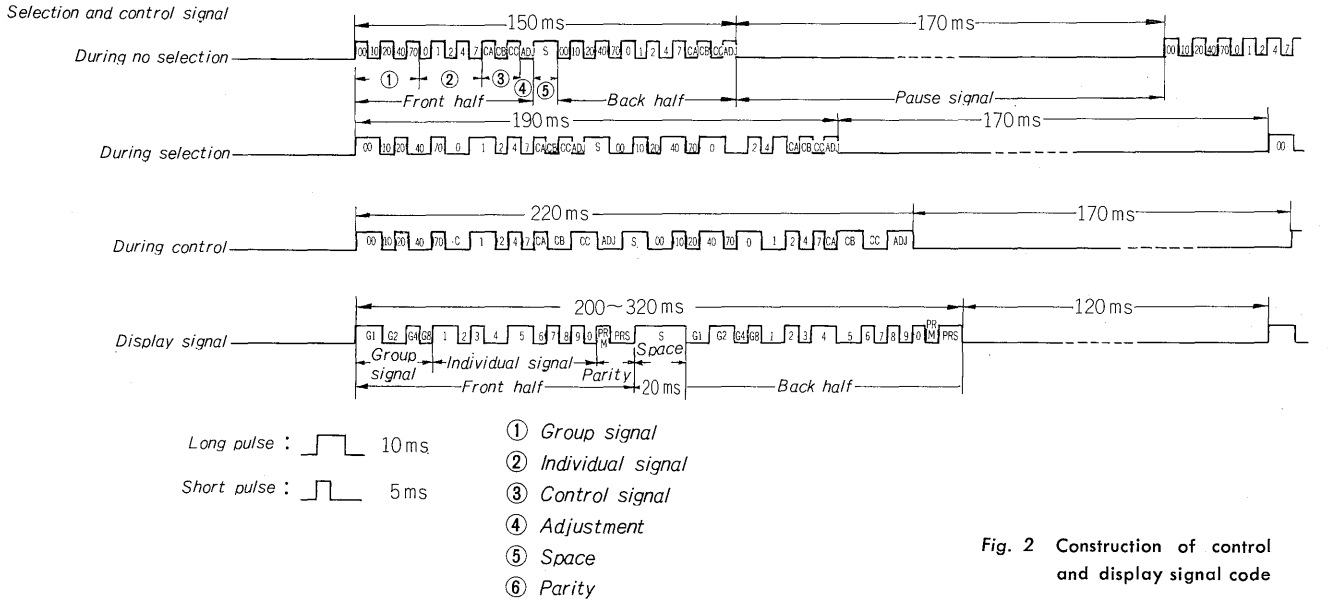


Fig. 2 Construction of control and display signal code

and 1,200 Hz as shown in specifications (7) and (8) are modulated with a frequency shift of ±100 Hz in order to achieve a signaling speed of 200 bauds, (200 bauds are also 4 channels). In cases when there is no tolerance in the transmission lines, it is also possible to use 50 baud transmission of 170 Hz width. A cyclic code transmission system is employed which provides normal cyclic transmission no matter what the changes in control and display item conditions.

1. Selection and Control Code

The construction of the code for the TC-100 URD is shown in *Fig. 2*. There are three condition in selection and control code selection: no selection, selection and control. In order to divide the system in 100 positions, a group of units each with 10 positions is provided. Ten of these units are used to make a total of 100 positions. The code which indicates the groups is a ${}_5C_2$ code which has two long pulses among 5 pulses. This is divided into 10 groups. The same ${}_5C_2$ codes are used for the individual codes which indicate the 10 positions. In other words, there are 10 groups × 10 individual = 100 positions.

Generally control operation in remote control is a double-action system. In the first stage the device to be controlled is selected by a selection switch and then either an ON or an OFF command is given by the master control switch. In such cases, when no selection is made, the code is transmitted cyclically completely in the form of short pulses. As is shown in *Fig. 2*, the code is divided into the front and back halves by a space so that there is repetitive transmission in order to avoid signaling errors. Both halves have the same code contents and if the check on the receiving side is satisfactory, the code is accepted. During no selection, one cycle with a signal time of 150 ms and a signal pause period of 170 ms is normally transmitted cyclically.

When a selection is made, a code which indicates the position specified by the ${}_5C_2$ group and individual codes described previously is transmitted. There are cyclically repetitive transmissions and the signal is transmitted as long as the selection operation continues. When a control operation is performed, the control code ${}_3C_2$ is transmitted in addition to the ${}_5C_2$ group and individual codes. Since three groupings are made with the ${}_3C_2$ code, one of these, i.e. ON control, OFF control or spare can be used depending on requirements. The control code is also transmitted cyclically while the master control switch is operating. The adjustment code transmitted after the control code is transmitted in the form of long pulses when there is a position which requires a continuous command for a long period in the remote station such as during adjustment control. During ordinary control, the ON and OFF commands at the remote station are only given for one second, but in positions where the adjustment code is long pulses, the commands continue in the remote station until the master control switch is reset.

The codes employ pulse duration modulation (PDM) in which there are conversion points from pulse mark to space and space to mark at each bit. The long pulse (1) or the short pulse (0) is selected by making the time until the next conversion point long or short depending on the stipulations. The amount of data transmitted per unit time with the PDM code is not large but the synchronous circuits for code transmission and reception are simple because of bit synchronization. In remote supervisory control equipment, the amount of data to be transmitted is very small but it is necessary for the reliability to be very high. Therefore, the PDM system is considered to be the most appropriate. The ratio between the long and short pulses must be determined in consideration of the amount of noise, distortion, etc. in the transmission lines and generally, the larger this ratio, the worse the changes in the various required factors and the external conditions. However, as can be seen from *Fig. 2*, the contents of the code which is transmitted twice in front and back halves is the same, but by reversing the mark and space positions, it can be easily detected errors caused by increase in code distortion. Therefore, in this equipment, the ratio between the long and short pulses is 2 : 1.

2. Display Code

The cyclic transmission system is also employed for the display code. In this way, all display item conditions in remote station are ordinarily transmitted in sequence to the master station. In other words, as in the case of the control codes, all display positions are divided into 10 groups and the code for each group is constructed as shown in *Fig. 2*. Transmission is cyclic by means of the PDM code. The first four bits G_1, G_2, G_4 and G_8, specifiy the 10 groups according to a binary code. The next 10 bits, 1, 2, 3 . . . 10, are the display bits and each bit corresponds to a condition of devices in the remotestation. When the device is ON, the bit becomes a long pulse (1) and when the device is OFF, the bit becomes a short pulse (0). In the example shown in *Fig. 2*, the "5" pulse is used and the group code becomes $1100 \rightarrow 1 \times 2^0 + 1 \times 2^1 + 0 \times 2^2 + 0 \times 2^3 = 3$. Since this designates four groups in this equipment, it indicates that the device of position 45 is in the ON condition. The display code is transmitted twice like the control code and the front and back halves are transmitted by reversing the mark and space positions. The final parity check code checks the parity and the PRM bit changes between long and short so that there are odd numbers since it includes the number of marks. In the same way, the PRS bit includes the number of spaces and changes them so that there is an odd number. The continuous time for

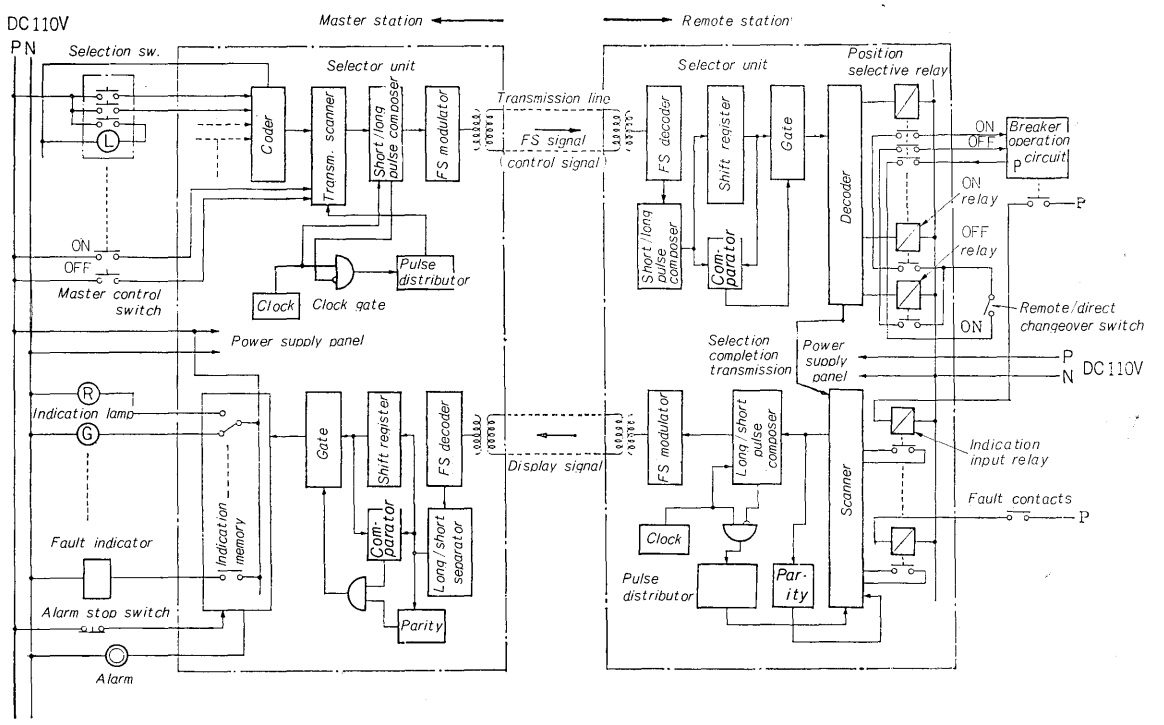


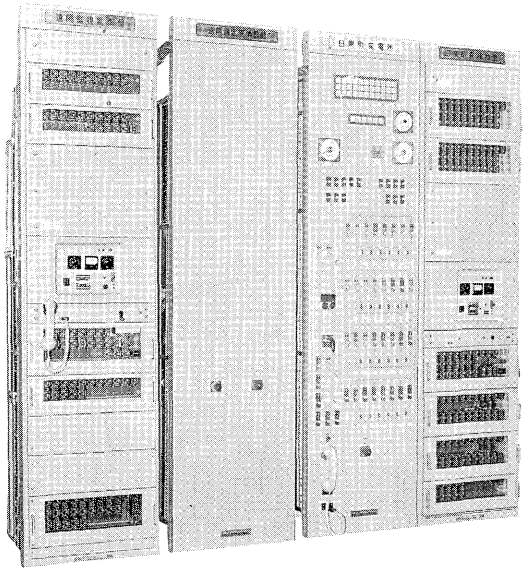
Fig. 3 Block Diagram of URD type remote supervisory control equipment

the display code is 200 to 300 ms and since the conditions of the devices included in the groups are not constant, the number of long and short pulses sometimes change in accordance with group differences and times.

When the display code contents of the first group are converted into the pulse code described previously, the second group is transmitted after the signal pause period (120 ms), and subsequently the third group, fourth group and so on up to the tenth group. One cycle is completed when transmission returns to the first group (refer to *Fig. 5*). These cycles are repeated. One cycle time is 3240 to 4280 ms (at 200 baud). When 50 baud transmission is required, the short pulse width becomes 20 ms and the long pulse width 40 ms. Therefore, the time for one cycle is about four times longer, and when there is a change in the condition of some group, the display can be delayed considerably since under the worst conditions the change is not confirmed at the master station until one cycle passes. For this reason, a priority circuit is used for 50 baud transmission.

IV. OPERATION

A block diagram of the equipment is shown in *Fig. 3.* The parts in the broken lines in this figure correspond to the parts in the equipment shown in *Fig. 1.* This figure shows the case when two pairs transmission lines are used, one for the control signal and one for the display signal. The remote supervisory control switchboard contains the selection switch, master control switdh, condition indicating



(1) (Remote station panel proper) (2) (Remote station converter panel)
(3) (Master station operation and supervisory panel)
(4) (Master station panel proper)

Fig. 4 Remote supervisory control switchboard

lamps, fault indicating lamps, etc. An example of such a switchboard is shown in *Fig. 4.*

1. Selection and Control

An example of control of a circuit breaker in the remote station is shown in *Fig. 3.* If the device is OFF before control, the condition display lamp G is lit by display memory output. Selective operation of the selection switch for this device is performed on the switch- board. Since the equipment can not give out more than one command simultaneously, the selection lock will be actuated if more than one

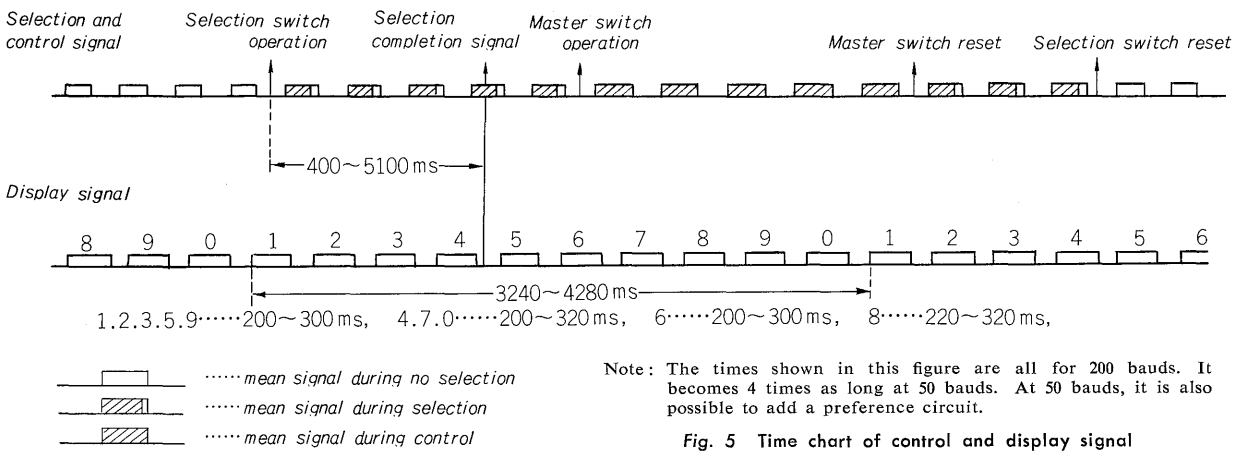
selection switch is operated simultaneously. Operation of the selection switch causes voltage P to be applied to the coder. The coder is composed of wire spring relays and by combining the relay contact, the group code ($_5C_2$) and the individual code ($_5C_2$) corresponding to the position of the device selected are applied in parallel to the transmitting scanner. The transmitting scanner is controlled by the pulses from the clock and the pulse distributor and normally scanning is repeated. However, at the time of no selection, there is no input from the coding circuit and as shown in *Fig. 2*, all input is converted into a series code of short pulses and transmitted. When there is an output from the coder, the output is scanned in sequence, applied to the long and short pulse composer and converted into long and short pulses. The results are the front half of the code during selection as shown in *Fig. 2*. Since the transmitting scanner operates twice in succession, the back half of the code is formed and the second code transmission occurs. This code is then modulated in the FS modulator and transmitted to the remote station in the form of an FS wave. The FS modulator is an LC signal generator employing transistors. The C value of the LC resonance is changed by the marks and spaces so that the signal frequency is also changed.

The FS wave which has reached the remote station first enters the FS demodulator and after being amplified once, it is reconverted into DC pulse marks and spaces by the frequency discriminator. This code enters a long and short pulse separator which consists of a delay circuit (timer) and when there are only long pulses, output appears and is applied to the shift resister. The shift register consists of a series of connected flip-flops and writes 1 when there is output from the long and short pulse separator (only long pulses) or 0 when there is no output. At the time when reception of the front half of the code is completed, the entire contents of the code are stored in the shift register. The back half of the code forces out one bit at a time the front half of the code which has already been stored in the shift register, and the new contents of the back half of the code are stored. The bits corresponding to front half and back halves of the code forced out at this time from the shift register are applied to the comparator and it is confirmed that the 1's (long) or 0's (short) agree. In other words, the double transmission is checked. After the code has been completely received, and if the check results are good and the total number of pulses is correct, the gate is opened and the contents of the shift registor are transferred to the decoder. At the time when signal reception is completed, the back half of the code is stored in the shift register. The decoder circuit consists of wire spring relays and if at the decoding stage, the $_5C_2$ is checked and found to be correct (constant total mark check), the specified position selective relay is operated. At this time, the operation of the position selective relay uses one display position which is returned to the master station (operation of the display circuits will be described later).

When the selection completion signal is received in the master station, this is indicated by a lamp contained in the selection switch. Once this is confirmed and the master control switch is turned to ON, the code according to the previous selection switch is added, these conditions are applied to the scanner, and the $_3C_2$ control code appears. The subsequent operation is the same as in the case of the selection operation described above. If the signal passes the same check as performed on the selection signal, it is applied to the position selective relay which is already operating, the control relay (ON relay) is operated, and an ON command is given to the device in question.

2. Condition Change Indication

When a device on the remote side (circuit breaker in *Fig. 3*) is turned on by a command, the ON condition of the auxiliary contacts operates the display input relay in the equipment. The contacts of this relay are normally monitored by the transmitting scanner. Since the distribution pulse from the



Note: The times shown in this figure are all for 200 bauds. It becomes 4 times as long at 50 bauds. At 50 bauds, it is also possible to add a preference circuit.

Fig. 5 Time chart of control and display signal

Table 1 Display pattern

Display system	Display pattern	Application
A system (momentary input)	Input: on / off; Signal lamp: (Flicker) 3-FL 3-IR	Operating conditions of relays for breaker tripping, reclosing circuits, etc.
B system (momentary or continuous input)	Momentary / Continuous; Input; Signal lamp: 3-FL 3-FL	Fault detection relay, etc.
C system	Input; (Red lamp); Signal lamp; (Green lamp) 3-FS 3-FS	Switch conditions (manual sw. is only for display reversing, etc.
D system	Input; Signal lamp	Limit switch condition display, sequeuce control stage display, etc.

(Note) 3FL : Flicker stopping operation
3IR : Display reset operation

pulse distributor is normally applied to the scanner, the ON and OFF conditions of the devices corresponding to each position are applied in sequence to the long and short pulse composer. The subsequent operations from the scanner to the FS modulator are based on control signal transmission and differ only in that a parity check bit circuit is added.

When the signal is received in the master station, the long pulses are separated by the same operation as in the case of the selection and control signal, and it is confirmed that the front and back halves of the double transmission agree. If at the same time the parity check and total pulse check are performed and the results are good, the gate is opened and the contents of the shift resister are transferred to the display signal memory which consists of wire spring relays. This display signal memory contains a display signal memory relay for each position. The ON/ OFF conditions of these relay contacts are transferred to the switchboard and the condition indication lamps light. If the ON condition of the device achieved is changed due to control, the condition indicating lamp G is turned off and lamp R is turned on.

Fig. 5 shows a time chart of the control and corresponding display signals. Each signal is shown in the diagram by a block but these parts are the same as those included in the pulse code shown in *Fig. 2.*

For condition display, it is possible to have a two lamps system such as the R and G lamps described above or a one lamp system for fault display. If necessary, it is is also possible to have the lamps flicker when a condition changes. Bell or buzzer alarms can also be used for fault display. The display patterns can be set beforehand in the display memory circuit in accoodance with each of the positions designated. The main display patterns are of four types: A, B, C and D as shown in *Table 1.* Each display input condition display can be applied to these four types of patterns.

In positions which receive momentary input contacts in the remote station, self holding occurs at the same time as the display input relay operates so that the scanner can always perform scanning. After confirmation of a fault, this hold is released by display reset operation using one control position from the master station.

V. EUQUIPMET CONSTRUCTION

As can be seen in *Fig. 1,* this equipment consists of a master and remote station together in a single unit. The dimensions are given in II-2 and conform to the standards for distribution panels in JEM-1133. This equipment can therefore be arranged beside, behind or in front of other distribution panels.

The equipment is designed to utilize the features of semiconductors such as transistors and diodes, and electromagnetic relays. Generally semiconductors have a high operating speed, a long service life not related to operating time and complicated circuit construction. Their disadvantages are a low withstand voltage and a small power capacity. In the case of electromagnetic relays, the operating speed is slower than that of semiconductors, life is determined by the number of operations and circuit construction is comparatively simple. However, they have high voltage withstands and large power capacities unlike semiconductors.

When these properties are considered in the case of remote supervisory control equipment, input/output circuits connected directly to power devices have a low frequency of operation and the power levels are high: therefore relays are appropriate. However, since common circuits for code reception and transmission require a high frequency of operation, a complex logic construction and high operating speeds, such circuits should be composed of semiconductors. Because of the above considerations, semiconductors are used in the common circuits and electromagnetic relays are used in the input/output circuits so that the features of each can be utilized to the utmost.

1. Electronic Circuits

The electronic circuits consist of semiconductors as described above and are the common circuits for code transmission and reception, as well as carrier parts. Approximately 50 printed boards are used each in the remote and master stations for these circuits.

2. Relays

All of the input and output section in both the remote and master stations consist of wire spring relays. These relays are in units of 20 positions and

are accomodated in dust proof relay box. Since these box are of the plug-in type, attachment and removal are easy.

The relay circuits of the master station are shown in *Fig. 3*. They are the coding and display memory circuits and there are two display output relays for each position, one for display memory and one for flicker memory. As was described in IV-2, relay panel terminals can be provided for one lamp or flickers and alarms. Optional design is possible.

The relays in the remote station are the position selective relays and display input relays for each position, and the common relays such as the decoder. The wire spring relays are of the twin WK type used in the remote and master station for compactness. However, the relays in control output parts which are directly connected to power devices such as circuit breakers present a problem in respect to contact switching capacity. Therefore, a power relay with 110 V 10 A switching capacity is used as a common ON and OFF relay for all positions. This relay can bear the switching load and power flows only in the wire spring relays for position selection.

3. Power Supply

In remote supervisory control equipment, it is essential that the controlled device operates correctly even when there is a fault. Therefore, the power supply must be of the non-interrupting type. Non-interrupting type power supplies in ordinary substations are often batteries (110 V DC). These batteries are neutrally grounded at normal high impedances and the grounding circuit must have a voltage withstand of 2,000 V AC for more than one minute in respect to ground. Since this power supply is to be used to supply operating power to power devices such as circuit breakers and disconnecting switches, there is the problem of the penetration of surge voltages from the power devices. The voltage variation range is very wide, −20 to +30%. Therefore, there are many unfavorable points in the use of batteries as a power source for electronic circuits.

However, if a DC/DC converter is used, insulation between the battery and the electronic circuits, and voltage stability can be achieved. The disadvantages of such equipment are complexity and high price.

Therefore, in this equipment, a voltage divider method for the battery voltage using a resistance and rectifiers (selenium and silicon) as shown in *Fig. 6* is used to provide accurate, low cost power. With this method, the power supply circuit is very simple and the forward voltage current characteristics of the rectifiers have constant voltage characteristics so that changes in the output voltage in respect to load and input voltage changes are small. Input voltage variations can be kept down to about 30%.

This is highly advantageous, especially in that a constant voltage circuit is not required. Formerly in this type of constant voltage divider circuit, it was

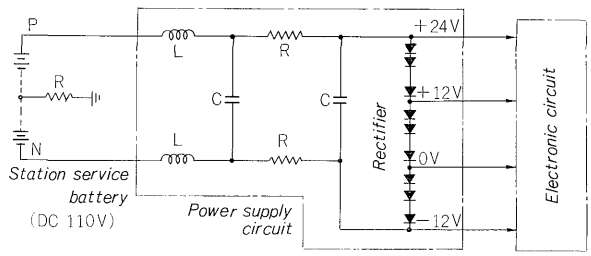


Fig. 6 Power supply for electronic circuit

necessary that a current the same as the total load be supplied even when the load was small. However, in this equipment, the series resistance value is altered by the number of loads and the power can be reduced at the time of a light load.

The problem of voltage withstand is solved by attaching all the electronic circuit parts so that they are electrically insulated from the panel. The penetration of surges from the battery side is completely eliminated by the use of an LC filter for the high frequency component and an RC filter for the low frequency component. A special rectifier type power supply panel is provided for the case when a non-interruptable AC power supply is used.

VI. EQUIPMENT FEATURES

The features of this equipment are as follows:

(1) The circuits have been designed to utilize the features of semiconductors such as transistors and diodes, and electromagnetic relays to the utmost.

(2) The ambient temperature range is very wide since silicon semiconductors are used.

(3) Since the repetitive transmission code checking system is used, circuit construction is very simple, complex circuits like the control and display signal priority circuits used in the former loop check system are not required, and the circuits for control and display are completely separate. This means that simultaneous transmission of control and display is possible.

(4) Since the signals are transmitted by a cyclic system, condition change detection circuit and simultaneous generation circuits like those used in the random system are not required and the circuit is thus much simpler.

(5) Because of the used of PDM which makes bit synchronization possible for the pulse code, synchronous circuits in the code transmission and reception parts are greatly simplified.

(6) It is easy to set the condition change display patterns in the master station.

(7) Since a subcarrier is used for transmission of signals between the master and remote stations, the codes can be transmitted at high speeds over long distances without distortion and special lines such as microwave carriers and power line carriers can also be connected easily.