SWITCHING CAPACITORS AUTOMATICALLY IN RESPONSE TO CHANGES IN LOAD REACTIVE KVA.

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Instruction Book 7162 - 2

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Westinghouse Electric & Manufacturing Company

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INDEX

DRAWING LIST

SUPPLEMENTARY INSTRUCTIONS

SWITCHING CAPACITORS AUTOMATICALLY IN RESPONSE TO CHANGES IN LOAD REACTIVE KVA.

PURPOSE

The Switching of Capacitors Automatically is sometimes desirable to keep the demand and losses to a minimum for various load conditions. The Equipment used for switching capacitors is an assembly of standard switches and relays similar to that used for other applications such as Automatic Substation Equipment. Usual periodic inspection and maintenance is of course desirable as is true for other electrical equipment such as Motor Starting Equipment or Automatic Substation Equipment. Care in Handling, Unpacking, Adjusting and Maintenance are important as described under those headings. It is desired that this Instruction Book shall be found adequate and useful in all the problems from the receipt of the product through continued service. Requests for additional information are welcomed.

DESCRIPTION OF APPARATUS

The Equipment consists of an electrically operated Air or Oil circuit breaker for each capacitor group to be switched, plus a Control Panel with the following devices: An RKVA Responsive Relay which initiates the switching operation, Time Delay Relays to prevent unnecessary switching operations due to momentarily circuit disturbances, the necessary number of Auxiliary Switches and Contactors to obtain the proper sequence of operation and handle the energizing and de-energizing of the closing and tripping circuits. For three or more Step Control a Motor Operated Controller Unit is used to obtain the desired sequence of the switching operations instead of auxiliary switches and contactors.

In some cases the circuit breaker and control panel are supplied assembled into the capacitor housing, similar to those described in Instruction Book 5704. In other cases the control panel may be enclosed in a Separate Sheet Steel Enclosure for mounting separate from the capacitor housing. The Circuit Breaker may also be mounted separate from the capacitor housing.

The RKVA regulating relay is an alternating current two coil type with the operating parts combined into one moving element. Each coil has three windings consisting of a voltage winding and two current windings. The current windings on each coil are connected so that they magnetically oppose each other but when combined with the voltage winding and energized at a phase angle of 90° between the current and voltage there is no torque developed. Capacitors and resistors are connected in series with the voltage windings to adjust the power factor to unity and balance the current. If the phase angle of the current is shifted in the lagging direction this results in a torque to rotate the lever in a counter clockwise direction and if it is shifted in the leading direction, the rotation of the lever is in a clockwise direction. Weights are suspended from the adjustable brackets

at the ends of the moving lever. The rotation of the lever in a counter clockwise direction a certain distance engages the suspended weights on the right to restrain its movement and rotation of the lever in a clockwise direction a certain distance engages the suspended weights on the left to restrain its movement. The movement of these weights requires a torque proportional to the weight. Since the weights are not suspended from the moving lever it is possible to adjust the pick-up of the upper or lower contact independent of each other by varying the weights that affects the particular contact involved. Weights may be added to the right of the pivot center of lever arm to have both contacts pick up in the lagging quadrant. Permanent magnets are located above the moving lever near each end to obtain quick "make" and quick "break" of the relay contacts.

The current windings of each coil have a burden of approximately 10 volt-ampere at 5 amperes and the voltage winding of each coil has a burden of approximately 10 volt amperes at 115 volts, 60 cycle.

A motor operated sequence switch which consists of a single phase reversible AC motor, a gear reduction unit and necessary Mercury switches operated by cams is used to obtain the desired sequence of operation on the three or more step automatic control units. Two type TK Timing Relays are used in this case as a means of providing a time interval between the closing of the RKVA regulating relay contacts and the operation of the circuit breaker.

The 230 to 575 volt capacitor equipments usually have Air Circuit Breakers which are equipped with overcurrent protection and a bell alarm contact which opens a circuit to lockout the control devices when the breaker is tripped from overcurrent. The higher voltage capacitor equipments (2400 volts and above) usually use oil circuit breakers without overcurrent trip attachments for switching the capacitors. In this case, line type BA fuses or a master breaker is used for overcurrent and short circuit protection.

SAFETY FOR PERSONNEL

Capacitors should be removed from service by opening the circuit breaker. BEFORE TOUCHING ANY OF THE CAPACITOR CONNECTIONS WAIT FIVE MINUTES FOR THE STORED ENERGY TO DISCHARGE THROUGH THE DISCHARGE DEVICES, THEN SHORT CIRCUIT EACH PHASE. The Discharger drains the stored charge and reduces the voltage to 50 volts or less in the specified time so that the terminals may be shorted without causing a serious arc. ALWAYS SHORT CIRCUIT CAPACITOR TERMINALS BEFORE TOUCHING ANY CONNECTIONS. Use a piece of wire insulated for the operating voltage of the capacitor with ends bare for about one inch.

HANDLING, UNLOADING AND UNPACKING

Upon receipt of the switching equipment and control, a

thorough inspection should be made to see that no parts have been broken or otherwise damaged during shipment. Any damage which has occurred should be taken care of by restoring the parts to the original condition or by obtaining replacement parts from the manufacturer. Claims for damage during shipment should be taken up at once with the Transportation Company.

If the switching equipment and control panel are assembled in the capacitor housing, the equipments are usually shipped completely assembled, except for the capacitor units, fuses and WEMCO "C" oil, if oil circuit breakers are supplied. In this case the housing, capacitor units, fuses and oil are shipped in separate containers. The capacitor units should be unloaded, unpacked and handled in a manner to prevent damaging the porcelain bushings or case. If the breaker is not to be assembled in the capacitor housing then it will be shipped separately. The housing with the control relays should be carefully handled to avoid damage to relays.

FOUNDATIONS

The indoor equipments do not, as a rule, require a special foundation so long as the floor will satisfactorily carry the weight. It is suggested that a concrete slab be provided for outdoor equipments located on the ground.

INSTALLATION & ERECTION

The equipment is sometime supplied and shipped with the control panel mounted in the capacitor housing and in some cases it is supplied and shipped in a separate sheet steel enclosure. The capacitor units, fuses and oil if supplied are shipped separately. If the control panel and circuit breaker are assembled in the capacitor housing, the housing should be so located that the ambient temperature of surrounding surfaces does not exceed the figure specified for the particular capacitor supplied and air can readily circulate from along the floor up through the capacitor rack. The installation of the capacitor rack and units is covered by Instruction Book 5704.

POWER CONNECTIONS

Connections are to be made from the power circuit to the circuit breaker and from the circuit breaker to the capacitor bus, see I.B. 5704 for choice of cable leads. If the breaker is shipped assembled in the capacitor housing the connections between the breaker and capacitor bus are usually made at the factory. The capacitor housing should be properly grounded using terminals provided for that purpose.

CONTROL WIRING

Install conduit and make connections from the current

transformer, potential transformer and control source to the control panel. If two or more steps are involved install conduit and make the necessary connections between switching units. The Purchaser is expected to provide a suitable control source unless operating transformers are ordered. The Purchaser is also expected to provide a suitable current and potential source for the RKVA responsive relay unless suitable current and potential transformers are ordered.

ADJUSTING AND TESTING

Under normal conditions the lever of the RKVA regulating relay is approximately horizontal and the distance between contacts is approximately 3/32" and the lever arm moves about 1/32" from mid position, before engaging the weights. With sufficient increase in lagging RKVA, the lever will rotate in a counter clockwise direction to close the upper contact. The value of lagging Reactive KVA. required to close the upper contact is controlled by adjusting the weights at the right end of the movable lever. With sufficient increase in leading RKVA, the lever will rotate in a clockwise direction to close the lower contact. The value of leading RKVA required to close the lower contacts is controlled by adjusting the weights at the left end of the movable lever. The permanent magnets are adjusted to have a spacing of approximately .04 inches to the lever arm when the contacts engage. This gives quick "make" and quick "break" action of the contacts.

With no weights on the weight holder stems and the voltage windings energized at 110 volts, 60 cycle and the current windings energized at four amperes the relay will close its upper contact when the power factor of the load reaches about 99 per cent lagging and close its lower contact when the power factor of the load reaches about 99 per cent leading. If the current is 2 amperes instead of four, the power will increase to about 98 per cent leading or lagging before the contacts will close. The addition of three weights that are 1/2 inch in diameter and 1/16 inch thick on the right hand weight holder will not effect the pick-up of the lower contacts but will effect the pick up of the upper contact. These three weights will cause the upper contacts to close when the load power factor reaches about 98 per cent lagging with four amperes flowing. If the current is reduced from four amperes to two amperes the power factor will increase to about 90 per cent lagging before the upper contacts will close. Twelve weights 1/2" dia. by 1/16" thick on the right hand weight holder and with four amperes flowing in the current winding the load power factor will increase to about 80 per cent lagging before the upper contacts close. If the current is reduced from four to three amperes the load power factor will increase to about 61 per cent lagging before the upper contacts close.

Without any weights on the right or left hand weight holders a spread is found between the pick-up values of the upper and lower contacts. In order to make both pairs of contacts pick-up in the lagging quadrant add some weights on the right hand weight holder and also some weights on the top of the lever under the screw about 1-1/2" on the right of the pivot point of the movable lever.

If a greater spread is required this can be accomplished by adding weights on the weight holders.

The amount of RKVA spread required depends upon the size of the capacitor being switched. The relay should always be adjusted for a greater RKVA spread than the maximum KVA. rating of the capacitor being switched to prevent hunting.

The motor-operated sequence switch is designed to tilt the mercury switch contacts in a definite adjustable program. This is accomplished by means of cams which operate rocker arms carrying the mercury switches. These cams are mounted on a cam shaft which is rotated by a suitable geared motor through interchangeable gears. The cam surface is produced by two or more identical cams. These can be rotated in relation to each other so that the dedent or low part of the cam surface can be increased or decreased lengthening or decreasing the ON or OFF period. The cams are adjusted before they leave the factory to provide the desired sequence of switching operations.

TEMPERATURE & VENTILATION

The capacitor must depend on natural air circulation for cooling. Location in a dead air space should be avoided, nor should any enclosure or covering be used that will reduce the natural flow of air between the units. Radiation from nearby hot surfaces may prevent efficient cooling. The ambient temperature of the surrounding surfaces should not exceed the figure specified for the particular type of capacitor supplied.

LUBRICATION

The motor-operated sequence switch should be oiled about every three months with a high grade lubricating oil which will not congeal at low temperatures. See Instruction Leaflet 41-366 for lubricating the type TK relay.

OPERATION

If operating transformers are supplied with the equipment they are usually intermittently rated and therefore, should not be used to close or trip the circuit breaker oftener than once or twice in a one minute interval. In the case of three or more step control, the position of the cams on the motor operated sequence switch device 34 should be observed and the capacitor switches should be opened or closed to match before placing the equipment on automatic control. When the equipment is operated from automatic control the timing relays should prevent the transformer being operated beyond its thermal rating. Care should be exercised if the breaker is being operated by means of a hand-operated type W control switch to avoid using the transformer for opening and closing the capacitor switch oftener than twice in any one minute interval. The time interval will also permit the capacitor to be discharging through

the discharge devices before being re-connected to the circuit.

The type DK-15, DK-25 and DA-50 air circuit breakers may be operated manually by means of the hand-operating lever. If no control switches are supplied and the circuit breakers are being operated manually the fuses in the control circuit should be pulled to prevent operation of the control devices. The automatic breakers should be equipped with a bell alarm contact which opens a circuit to lockout the automatic control relays if the breaker is tripped from overcurrent. Type "W" control switches are usually supplied with the control panel where air or oil circuit breakers are used for switching the capacitors. These control switches are for use in closing or tripping the breaker by hand. In this case, a type "W" control transfer switch is supplied for changing to or from "Manual" or "Automatic" control.

FOUR STEP CONTROL WITH TYPE DA-50 CIRCUIT BREAKERS

The following is a Description of Operation for a four step control with type DA-50 breakers as detailed schematically on Dwg. 14-A-7021 when placed on Automatic control.

RKVA Responsive Relay, Device 55

When the lagging RKVA increases to the setting of the RKVA relay device 55, this relay closes its 55R contact.

Time Delay Closing Relay, Device 2

When the RKVA relay contact 55R closes time delay closing relay, device 2 will commence to operate to close a contact 2 in the circuit to the motor-operated sequence switch device 34.

Motor Operated Sequence Switch, Device 34

If the motor-operated sequence switch is in the #1 cam position and if the lagging RKVA remains at or above the setting of the RKVA relay for the time required for device 2 to close its contact 2, then the motor-operated sequence switch is energized to rotate the cams. If the cams are rotated from the #1 to the #6 cam position, mercury switch #9 closes when #2 cam position is reached. Mercury switch #2 opens the circuit to trip coil 52-1, when #4 cam position is reached, and mercury switch #1 closes when #6 cam position is reached to energize the auxiliary contactor 52-1X.

Auxiliary Contactor, Device 52-1X

Upon closing of #1 Mercury Switch device 52-1X will be energized and will close a contact to energize the Rectox solenoid-operated closing mechanism of the capacitor switch device 52-1.

Capacitor Switch, Device 52-1

When 52-1X closes its "make" contact, the closing coil of the capacitor switch 52-1 is energized and the switch closes to

connect #1 capacitor to the line. The closing operation of the switch device 52-1 operates auxiliary switches to close contacts in circuit to auxiliary contactor 52-1Y and to trip coil 52-1.

Auxiliary Contactor, Device 52-1Y

The closing of auxiliary contactor 52-1Y closes a contact to its coil and opens a contact in the auxiliary contactor 52-1X. The de-energizing of device 52-1X opens the circuit to the Rectox solenoid-operated closing mechanism of device 52-1.

RKVA Responsive Relay, Device 55 and Timing Relay, Device 2

If after the #1 capacitor is connected to the line the lagging RKVA still remains at or above the setting of the RKVA relay, the timing relay will remain closed and the motor-operated sequence switch will be rotated to the #10 cam position. If the lagging RKVA decreases momentarily then increases above the setting of the RKVA relay device 55, then the timing relay device 2 will re-set and a time interval will be imposed, before the contacts of device 2 close, to cause the motor-operated sequence switch to rotate.

Motor-Operated Sequence Switch, Device 34.

If the motor-operated sequence switch rotates from the #6 to the #10 cam position, Mercury Switch #4 opens the circuit to trip coil 52-2 when the #8 cam position is reached and closes Mercury Switch #3 when the #10 cam position is reached. The closing of #3 Mercury Switch energizes the auxiliary contactor 52-2X. The auxiliary contactors 52-2X and 52-2Y together with the auxiliary switches perform to close the capacitor switch 52-2 and place the #2 capacitor on the line same as described previously for placing the #1 capacitor on the line.

RKVA Responsive Relay, Device 55 and Timing Relay, Device 2

If after the #2 Capacitor is connected to the line the lagging RKVA still remains at or above the setting of the RKVA relay, the timing relay device 2 will remain closed and the motor-operated sequence switch will be rotated to the #14 cam position. If the lagging RKVA decreases momentarily then increases above the setting of the RKVA relay device 55, then the timing relay device 2 will re-set and a time interval will be imposed, before the contacts of device 2 close, to cause the motor-operated sequence switch to rotate the cams.

Motor-Operated Sequence Switch, Device 34

If the motor-operated sequence switch rotates from the #10 to the #14 cam position, Mercury Switch #6 opens the circuit to trip coil 52-3 when the #12 cam position is reached and closes Mercury Switch #5 when the #14 cam position is reached. The closing of #5 Mercury Switch energizes the auxiliary contactor 52-3X. The auxiliary contactors 52-3X and 52-3Y together with the auxiliary switches perform to close the capacitor switch 52-3 and place

#3 capacitor on the line same as described previously for placing the #1 capaciotr on the line.

RKVA Responsive Relay, Device 55 and Timing Relay, Device 2

If after the #3 capacitor is connected to the line, the lagging RKVA still remains at or above the setting of the RKVA relay, the timing relay, device 2, will remain closed and the motor-operated sequence switch will be rotated to the #18 cam position. If the lagging RKVA decreases momentarily then rises above the setting of the RKVA relay, device 55, then the timing relay device 2 will re-set and a time interval will be imposed before the contacts of device 2 close, to cause the motor-operated sequence switch to rotate the cams.

Motor-Operated Sequence Switch, Device 34

If the motor-operated sequence switch rotates from the #14 to the #18 cam position, mercury switch #8 opens the circuit to trip coil 52-4 when the #16 cam position is reached and closes mercury switch #7 when the #18 cam position is reached. The closing of #7 mercury switch energizes the auxiliary contactor 52-4X. The auxiliary contactors 52-4X and 52-4Y together with the auxiliary switches perform to close the capacitor switch 52-4 and place #4 capacitor on the line same as described previously for placing #1 capacitor on the line. The #10 mercury switch is used to stop the motor-operated sequence switch when cam position #20 is reached.

Automatic Tripping, Device 58

If the motor-operated sequence switch is in the #20 cam position and the leading RKVA increases to or above the setting of the RKVA relay device 55 this relay will close its contacts 55-L.

Time Delay Opening Relay Device 62

When the RKVA relay contacts 55L close time delay opening relay device 62 will commence to operate to close a contact 62 in the circuit to the motor-operated sequence switch device 34.

Motor-Operated Sequence Switch, Device 34.

If the leading RKVA remains high for the time required for device 62 to close its contact 62, then the motor-operated sequence switch is energized to rotate from the #20 to the #15 cam position. Mercury switch #10 closes contacts in circuit to time delay relay 2 when #19 cam position is reached, Mercury switch #7 opens contacts in the circuit to auxiliary contactor 52-3X when #17 cam position is reached and mercury switch #8 closes the circuit to the trip coil

52-3 when the number 15 cam position is reached.

Capacitor Switch, Device 52-3

Upon the closing of Mercury Switch #8 the trip coil 52-4 is energized and the capacitor switch, device 52-4 opens to remove the #4 capacitor from the line. The opening action of the capacitor switch operates an auxiliary switch to open the circuit to the trip coil 52-4 and contacts open in the circuit to the auxiliary contactor 52-4Y.

RKVA Responsive Relay Device 55 and Timing Relay Device 62

If after the #4 capacitor is disconnected from the line the leading RKVA still remains at or above the setting of the RKVA relay device 55, the timing relay device 62 will remain closed and the motor-operated sequence switch will be rotated to the #11 cam position. If the leading RKVA decreases momentarily then increases above the setting of the RKVA relay device 55, then the timing relay device 62 will re-set and a time interval will be imposed, before the contacts of device 62 close, to cause the motor-operated sequence switch to rotate the cams.

Motor-Operated Sequence Switch, Device 34

If the motor-operated sequence switch rotates from the #5 to the #11 cam position, mercury switch #5 opens the circuit to the 52-3Y auxiliary contactor when #13 cam position is reached and mercury switch #6 closes when the #11 cam position is reached to close the circuit to the trip coil 52-3 to open the capacitor switch device 52-3 disconnecting #3 capacitor from the line. The opening of the capacitor switch operates auxiliary switches to open the circuit to the trip coil 52-3 and opens contacts in the circuits to the auxiliary contactor 52-3Y.

RKVA Responsive Relay Device 55 and Timing Relay Device 62

If after the #3 capacitor is disconnected from the line the leading KVA still remains at or above the setting of the RKVA relay device 55, the timing relay device 62 will remain closed and the motor-operated sequence switch will be rotated to the #7 cam position. If the leading RKVA decreases momentarily then increases above the setting of the RKVA relay device 55, then the timing relay device 62 will re-set and a time interval will be imposed, before the contacts of device 62 close, to cause the motor-operated sequence switch to rotate the cams.

Motor-Operated Sequence Switch Device 34

If the motor-operated sequence switch rotates from the #11 to the #7 cam position, Mercury Switch, #3 opens the circuit to the 52-2Y auxiliary contactor when #9 cam position is reached and Mercury Switch #4 closes, when the #7 cam position is reached to close the circuit to the trip coil 52-2 to open the capacitor switch device 52-2 disconnecting #2 capacitor from the line. The opening of the capacitor switch operates auxiliary switches to open the circuit to the trip coil 52-2 and open contacts in the circuit to the auxiliary contactor coil 52-2Y.

RKVA Responsive Relay, Device 55 and Timing Relay, Device 62

If after the #2 capacitor is disconnected from the line the leading RKVA still remains at or above the setting of the RKVA relay device 55, the timing relay device 62 will remain closed and the motor-operated sequence switch will be rotated to the #3 cam position. If the system voltage decreases momentarily then increases above the setting of the RKVA relay device 55, then the timing relay device 62 will be re-set and a time interval will be inserted, before the contacts of device 62 close, to cause the motor-operated sequence switch to rotate the cams.

Motor-Operated Sequence Switch, Device 34

If the motor-operated sequence switch rotates from the #7 to the #3 cam position Mercury Switch #1 opens the circuit to the 52-1Y auxiliary contactor when #5 cam position is reached and Mercury Switch #2 closes when the #3 cam position is reached to energize the trip coil 52-1 and open the capacitor switch 52-1 disconnecting #1 capacitor from the line. The opening of the capacitor switch operates switches to open the circuit to the trip coil 52-1 and open contacts in the circuit to the auxiliary contactor 52-1Y. The #9 Mercury Switch is used to stop the motor-operated sequence switch when #1 cam position is reached.

Overload Protection

The capacitor switches are usually equipped with overload trips to open the switch in the event of a fault in the capacitor bank. If a capacitor switch is tripped from overcurrent, a bell alarm contact opens. The bell alarm contacts are in series with the auxiliary contactor coils used for energizing the respective capacitor switch closing mechanism which prevents automatically re-closing the capacitor switch tripped from over-current until the bell alarm contact is re-set manually.

Four Step Control With Oil Circuit Breakers

The operation of the four step control with an oil circuit breaker is similar to that described for the Three step control with type DA-50 circuit breakers. The breakers are not equipped with overcurrent devices or bell alarm contacts.

MAINTENANCE

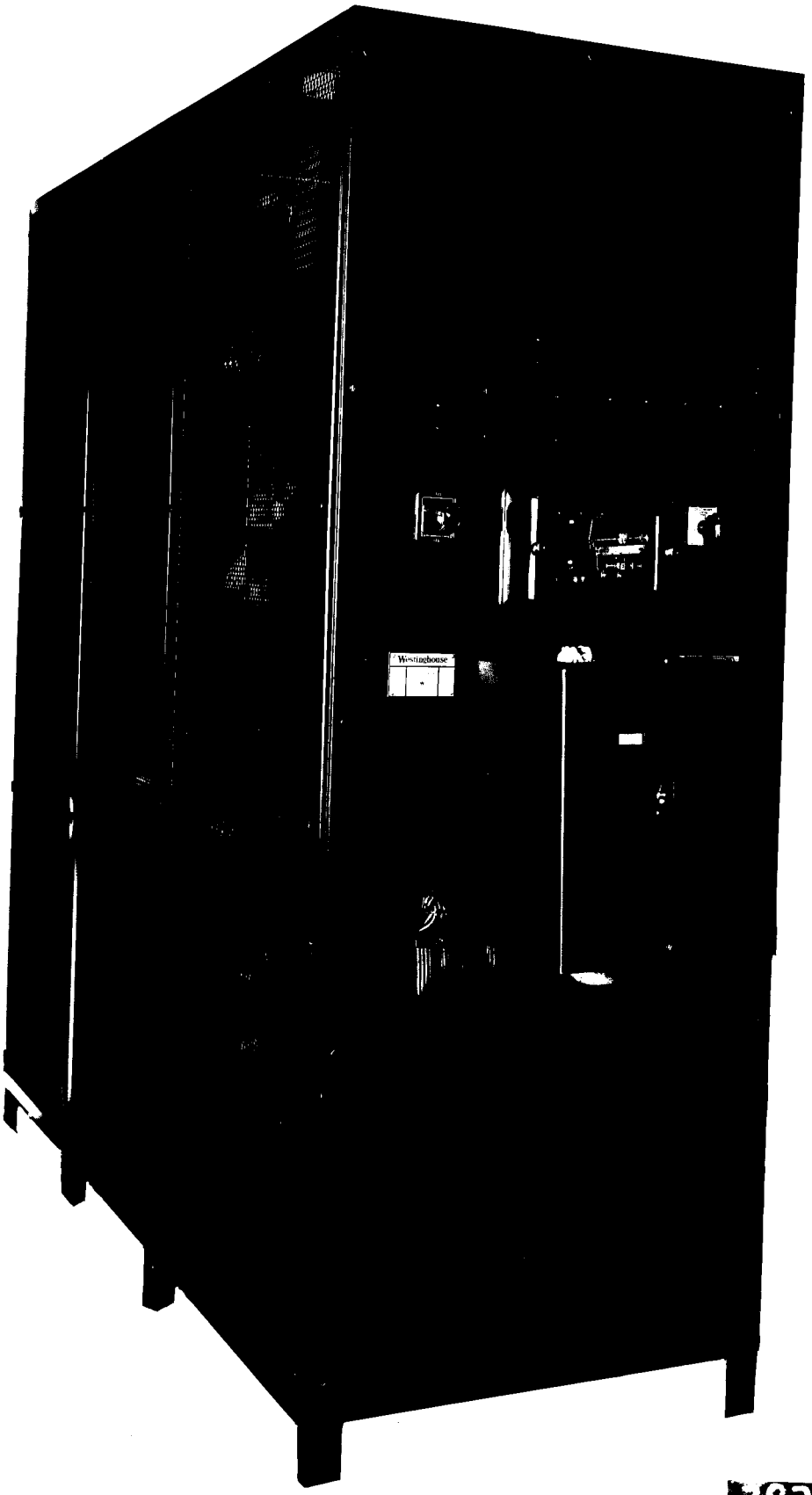
The automatic equipment shoulld be inspected periodically to insure good contact of the automatic control relay contacts,and cleanliness of the relays and their contacts. The operation should be observed every few weeks to insure that all devices are functioning correctly. Examine the capacitor switches periodically to see that the contacts are tight, line up properly and are in good condition. If oil switches are used the oil should also be examined or tested periodically to see that it is in good condition.

The capacitor units have no moving parts and, therefore,

require very little maintenance except an occasional inspection to note if a capacitor fuse has operated or if the circuit breaker has tripped from overcurrent or from capacitance phase unbalance if the equipments are provided with this latter feature.

RENEWAL PARTS

The capacitor units have no moving parts and there is practically no occasion to carry spare parts. For renewal parts list for the capacitor switches and control relays, see the Instruction Book or Instruction Leaflet for the particular circuit breakers and relays supplied.



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