Voltage Regulating Apparatus

32-Step Simplified Regulator Installation, Operating, and Maintenance Instructions

COOPER INDUSTRIES
McGRAW-EDISON POWER SYSTEMS

S225-15-1

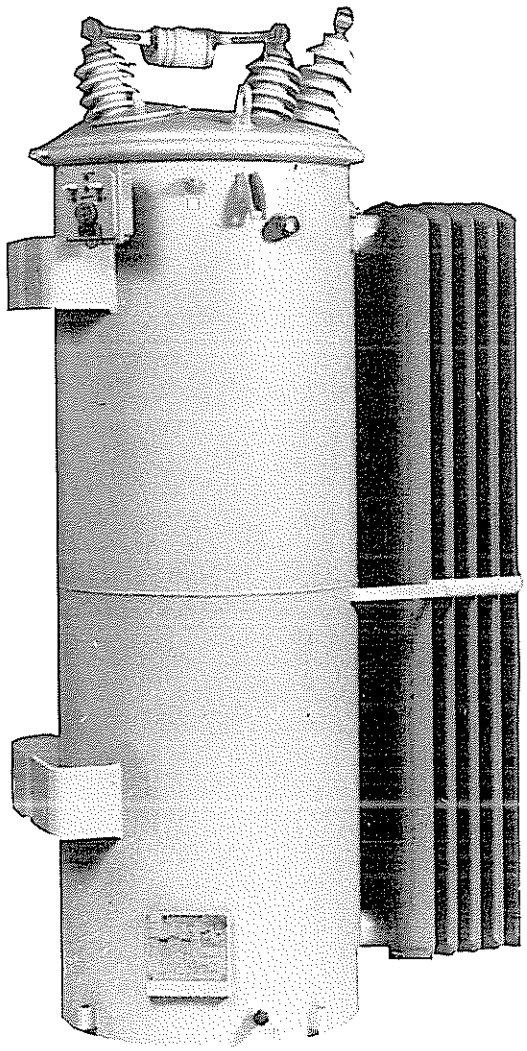


Figure 1
The McGraw-Edison simplified voltage regulator.

CONTENTS

GENERAL

The simplified regulator (Figure 1) corrects voltage from 10% boost to 10% buck in thirty-two (32) 5/8% steps (16 RAISE; 16 LOWER). A solid-state control actuates the tap changer in response to feeder voltage fluctuations. The control (Figure 2) features a fixed bandwidth ±1 volt, an adjustable voltage level setting, and manual or automatic operation. On the face of the control, light-emitting diodes (LEDs) that operate from a polarized switch on the regulator tap changer. One diode indicates when the tap changer is in any of the 16 RAISE positions; the other LED indicates when the regulator is in any of the 16 LOWER positions. In the neutral position, both RAISE and LOWER light-emitting diodes are off, and the neutral lamp (mounted on the tank) is lit, providing two checks for the neutral position. Another LED indicates when the voltage is out of band. A test plug monitors output voltage.

The philosophy behind this new regulator is simplicity; hence, simplified regulator. Offered without the complex accessories of the "regular" step-voltage regulators, the simplified regulator reduces maintenance costs as well as initial fixed costs.

These instructions do not claim to cover all details or variations in the equipment, procedure, or process described, nor to provide directions for meeting every possible contingency during installation, operation, or maintenance. When additional information is desired to satisfy a problem not covered sufficiently for the user's purpose, please contact your McGraw-Edison Power Systems Group sales engineer.

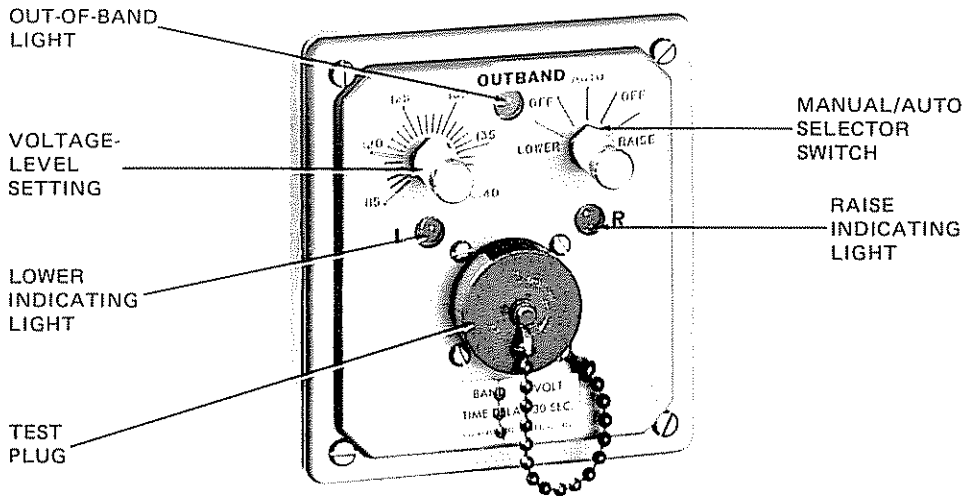


Figure 2

OPERATION

POWER CIRCUIT

Figure 3 illustrates the autotransformer circuit of a 32-step regulator which consists of a tapped series winding, a shunt winding across the regulator output terminals, and a potential winding closely coupled to the shunt winding.

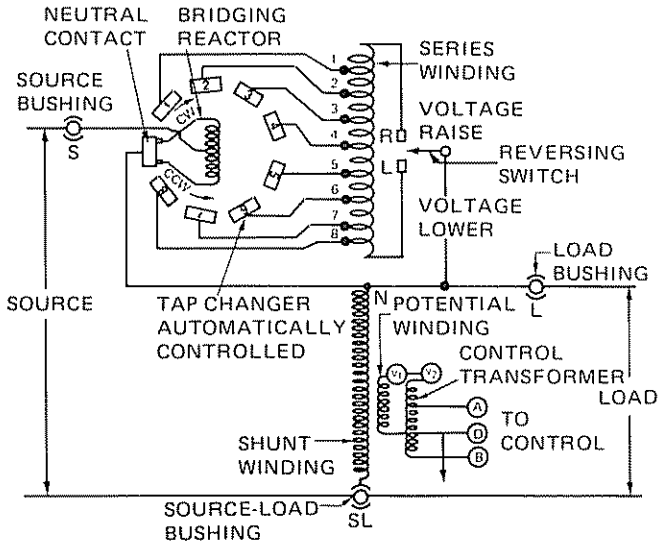


Figure 3
Power circuit.

The 10% series winding is tapped in eight sections of 1 1/4% regulation each. Taps are brought out to eight stationary contacts on the tap changer which has one neutral contact and two movable contacts connected by a bridging reactor. The center tap of the bridging reactor is connected to the source.

As the tap changer movable contacts operate clockwise from neutral, the reversing switch moves to VOLTAGE RAISE. Consequently, the series winding becomes subtractive with respect to the shunt winding and the amount of voltage boost depends upon the number of turns placed in series with the line. The reversing switch remains at VOLTAGE RAISE until the movable contacts return to neutral. When the movable contacts move counterclockwise from neutral, the reversing switch goes to VOLTAGE LOWER. The series winding, therefore, becomes additive with respect to the shunt winding. The amount of voltage buck depends upon the number of turns in series with the line. The reversing switch remains at VOLTAGE LOWER until the movable contacts return to neutral.

The bridge reactor assures smooth tap changes without current interruption or voltage dip. When the movable contacts are on neutral (Figure 3), no regulation occurs. When one movable contact is on neutral and the other is on Contact 1, only one-half of the 1 1/4% regulation occurs because the bridging reactor is tapped in the center. When both movable contacts are on Contact 1, 1 1/4% regulation occurs. As movable contacts travel from neutral to Contact 8, the tap changer passes through sixteen (16) 5/8% voltage steps. Because of the reversing switch, a total of 32 5/8% steps are obtained, ±10% regulation available.

The potential winding is coupled to the shunt winding in a ratio determined by the regulator voltage rating.

CONTROL CIRCUIT

The control circuit (Figure 4) provides automatic or manual control of the tap changer. A MANUAL/AUTO switch provides these positions in sequence: LOWER, OFF, AUTO, OFF, RAISE. In the AUTO position, the drive motor (Figure 5) returns are connected to the output triacs of the AUTO control (Items E and F). In other positions, the motor is disconnected from the AUTO control and the proper motor return is connected to ground to run the drive motor in the indicated direction.

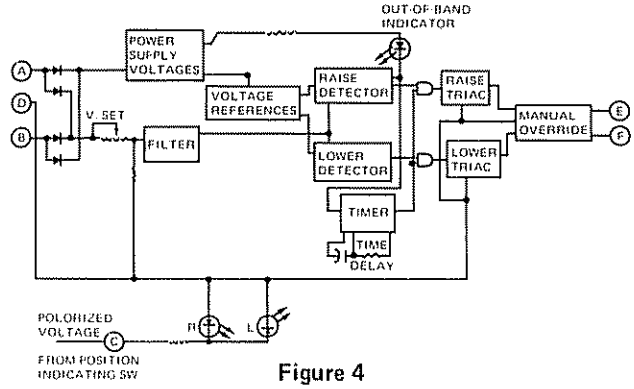


Figure 4
Control circuit.

In the AUTO mode, the voltage from the potential winding is compared with a preset desired level. If the voltage falls outside a band of ±1 volt at 120 V from the preset value, a time-delay sequence is initiated. At the end of the delay time, the proper triac is fired to drive the tap changer in a corrective direction. The control action is outlined in Figure 4 in conjunction with Figure 5.

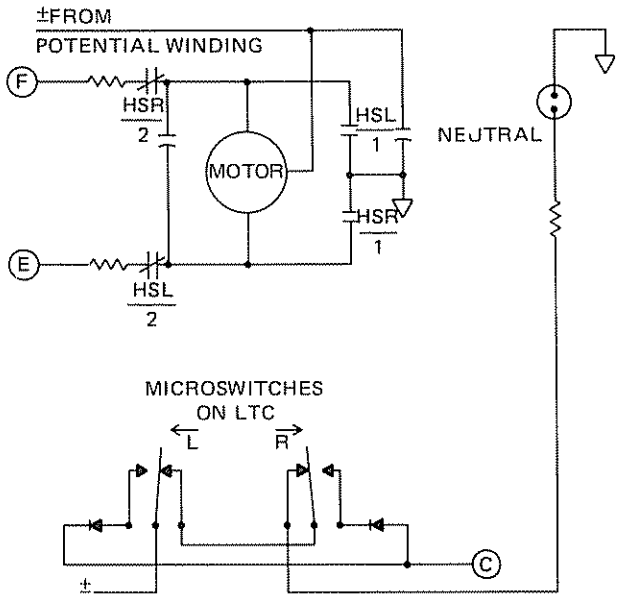
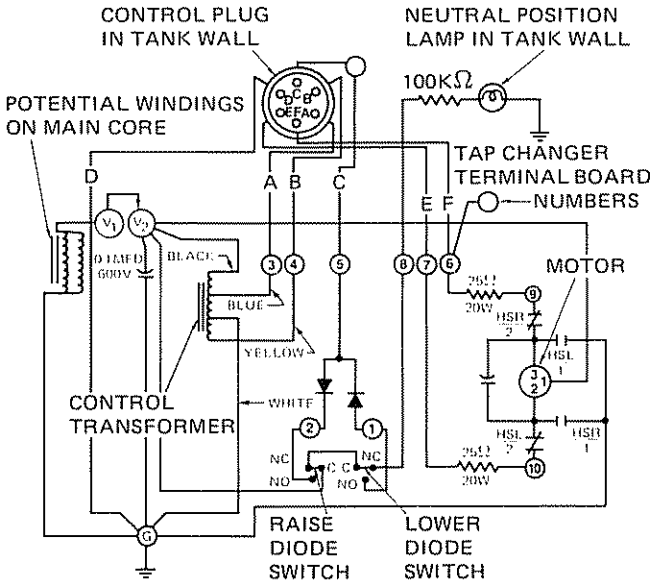


Figure 5
Automatic position.

A special control transformer connected to the potential winding yields a split supply to the control, which is one-half the potential winding voltage each side of ground (Figure 6). Two diode rectifiers are connected to this center tapped supply (Figure 4). One provides power to the circuit; the other, supplies a sensing voltage through a resistive divider.



SWITCHES ARE SHOWN WITH
TAP CHANGER IN NEUTRAL POSITION

Figure 6
Internal control circuit.

Reference voltages are generated from a Zener reference and a resistive divider. These voltages are applied to one input each of two comparators called detectors. The difference in these two reference voltages is the basis for the control bandwidth. The sensed voltage is filtered and applied to the other input of both comparators.

One output of each of the detectors goes low if the sensed voltage is out of band on that side. This initiates the timer and turns on an LED out-of-band indicator. The other output of either detector goes high when the sensed voltage is out of band on that side. This is ANDed with the output of the timer which goes high after the predetermined delay and the associated triac fires.

Time delay is set by an R/C timing circuit. The time is set basically at 30 seconds, but can be changed by changing the R of the time-delay resistor. A capacitor discharge circuit is incorporated to rapidly discharge the capacitor any time the input to the timer goes high, resetting the timer. Thus, the timer is quickly reset any time the sensed voltage goes in band.

The motor circuit (Figure 5) provides for a holding switch closure (HSL or HSR) to assure completion of a tap change. Resistors are provided in the triac returns from the motor to limit the triac current to an acceptable level under all conditions. (The triacs only have to initiate a tap change during which the motor torque requirements are low. The holding switch provides current for the higher torque required during the change.)

INDICATION

A pair of microswitches, connected as shown in Figure 5, is coupled mechanically to the tap changer reversing switch. When the reversing switch is centered (neutral), the supply from the sensing winding is fed through a series connection of the microswitches to the neutral light mounted on the tank.

If the reversing switch is off neutral, one of the microswitches is transferred. On one side, the supply is half-wave rectified by a diode to form positive pulses; on the other side, it is half-wave rectified by another diode to form negative pulses. The pulses (positive or negative) are fed through a current-limiting resistor to a pair of reverse connected parallel LED's (Item C, Figures 4 and 5). Positive pulses light one of the LED's, negative pulses light the other; indicating the L and R positions on the LEDs. In the neutral position, neither the L nor the R LED lights. Neutral is indicated by the tank-mounted light with—or without—the presence of a control.

RECEIVING INSPECTION

Prior to shipment, each simplified regulator is thoroughly tested and inspected at the factory. Immediately upon receipt of the regulator shipment—preferably before unloading—thoroughly inspect each regulator for damage, evidence of rough handling, and shortages.

Should this initial inspection reveal evidence of rough handling, damage, or shortages, file a claim immediately with the carrier. Also notify McGraw-Edison Company, Power Systems Division, Zanesville, Ohio 43701.

UNLOADING

When a simplified regulator is unloaded, lift it with a sling and spreader bar, using the lifting lugs on the regulator tank wall. **Do not lift the entire unit with the lifting eyes in the cover. These lifting eyes are to be used only to lift the internal assembly attached to the cover.**

STORING

If a regulator is not to be put into service immediately, it can be stored with minimal precautions:

1. Remove all packing materials that might possibly collect moisture.
2. Retain bracing and blocking securing and positioning the regulator.
3. Place the unit in a storage area where the possibility of mechanical damage is minimized.

WARRANTY

McGraw-Edison warrants that each distribution simplified regulator delivered to a purchaser is free from defects in material and workmanship. This warranty shall apply only to defects appearing within one (1) year from the date of shipment by the Company.

McGraw-Edison must be notified promptly of any defect that appears during proper and normal use of a simplified regulator within one (1) year from the date of shipment by the Company. The Company will have fulfilled its obligations under this warranty by repairing or replacing the defective part or parts.

PRE-INSTALLATION PREPARATION

1. Inspect the regulator.

   Each regulator is shipped with the switch mechanism in the neutral position, the voltage control set at 120 volts with a bandwidth of 2 volts, and a time delay of 30 seconds. Before connecting a simplified regulator to the line:

   A. Check the oil level gage.

   B. Examine the series arrester for damage. If damaged, install a new arrester of the same voltage rating.

   C. Inspect the bushings for damage or leaking seals. If there is a suspicion that mositure has entered the tank, dry the regulator and filter the oil before putting the unit in service. The oil must test 28 kv minimum in a standard gap (ASTM D 877).

   D. If the regulator has been stored, test the dielectric strength of the oil in accordance with the testing procedure of ASTM D 877. If the oil does not test a minimum of 28 kv, filter it.

2. Provide surge protection

   All simplified regulators are equipped with a bypass arrester connected across the series winding. A metal-oxide varistor in the control cabinet provides surge protection for the control unit. Surge protection is recommended for the shunt winding of the regulator. Refer to Table 1 for the recommended arrester for various applications. Refer to Figure 7 for the recommended number and locations of arresters

Table 1
Recommended Arrester Applications

System Voltage (kv)		Recommended Arrester Rating (kv)		
Nominal	Maximum	Four-Wire Wye-Multi-grounded Neutral	Three-Wire Wye-Solidly Grounded Neutral	Delta and Ungrounded Wye
2.4	2.54			3
4.16Y/2.4	4.4Y/2.54	3		
4.16	4.4		6	6
4.8	5.08		6	6
6.9	7.26		6	9
8.32Y/4.8	8.8Y/5.08	6		
12.0Y/6.93	12.7Y/7.33	9		
12.4Y/7.2	13.2Y/7.62	9		
13.2Y/7.62	13.97Y/8.07	10		
13.8Y/7.97	14.5Y/8.4	10		
13.8	14.5		12	15
20.8Y/12.0	22Y/12.7	15		
22.9Y/13.2	24.2Y/14.0	18		
23	24.3		21	24
24.9Y/14.4	26.4Y/15.2	18		
Common system voltages used outside the United States and Canada				
3.3	3.7		3	
6.6	7.3		6	
10.0	11.5		9	12
11.0	12.0		10	12
15.0	17.5		12	18
20.0	23.0		18	24
22.0	24.0		18	24

3. Connect the grounds.

   On a multigrounded wye system:

   A. Connect the ground to the clamp on each regulator tank, using a ground wire at least equivalent in size to the incoming phase conductors.

   B. Make the interconnection between the tank and the ground as short as possible.

      NOTE: If the grounds are not interconnected, neutral shift—with the resulting distortion of phase voltages—can occur because the independent control of each regulator can produce unequal turn ratios between phases.

   For a single-phase system:

   A. Connect the regulator ground to the system neutral.

      NOTE: A driven ground on the neutral is advisable.

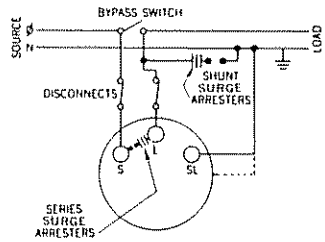
   For a delta system:

   A. Grounding the regulator tank is recommended.

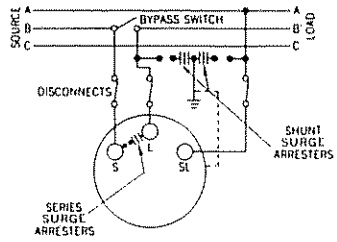
   B. Interconnect the tank ground with the surge arrester ground (Figure 7).

   If the control is located remote from the regulator:

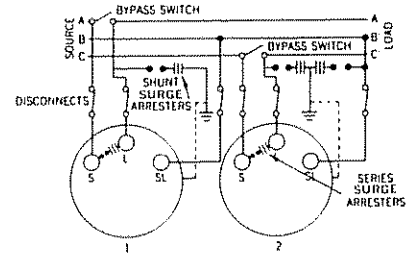
   A. Run a ground wire from the clamp on the control bracket to a driven ground rod.



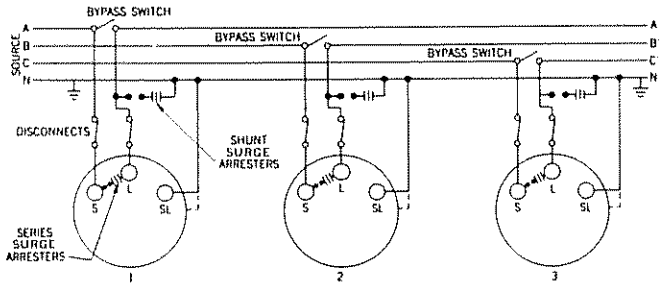
Regulating a single-phase circuit.



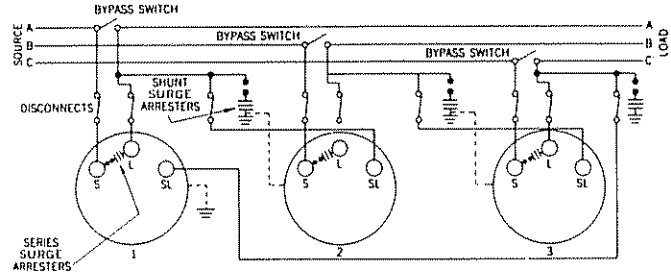
Regulating one phase of a three-phase, three-wire circuit



Regulating a three-phase, three-wire wye or delta circuit with two regulators.



Regulating a three-phase, four-wire, multi-grounded wye circuit with three regulators



Regulating a three-phase, three-wire wye or delta circuit with three regulators

Figure 7
Typical connection diagrams for 32-step regulators.

4. Check the solid-state control.

   Perform an operational check before installing the regulator.

> **CAUTION**
>
> The procedure outlined below is based on testing a completely oil-filled regulator. Continuous operation of the tap changer out of oil is harmful to the mechanism.

A. Connect the three high-voltage bushings together and ground them.

B. Turn the selector switch (Figure 2) to an OFF position.

C. Remove the handhole cover and, reaching through the handhole, pull the quick-disconnect terminal from the V_2 terminal on the tap changer terminal board (Figure 6), disconnecting the tap changer and control from the internal potential source.

D. Apply an external 120 volt source between V_2 and ground.

The control and tap changer can now be put through an operational check without energizing the regulator.

E. In the neutral position, both L and R LED's (light-emitting diodes) in the control are off and the neutral light in the tank wall is on, providing a double check on the neutral position for the installation on and the removal from a line.

F. Turn the selector switch to LOWER.

(1) At the first step off neutral, the L LED will appear and will remain on as long as the tap changer is in any LOWER position. (It will go off when the tap changer is returned to the neutral position.)

(2) Allow the tap changer to make several operations in the LOWER direction, then turn the selector switch to an OFF position.

NOTE: The tap changer holding switch will cause the tap changer to complete the operation in process.

G. Turn the selector switch to RAISE.

(1) Allow the tap changer to operate several steps in the RAISE direction.

(2) When the tap changer reaches the neutral position, the L LED will go off.

(3) Both the L and the R LED's are now off.

(4) At the first raise step off neutral, the R LED will go on and will remain on as long as the tap changer is in any RAISE position. (It will go off when the tap changer is returned to the neutral position.)

H. Turn the selector switch to AUTO.

(1) With the control in AUTO, adust the voltage-level setting so that the voltage is in band.

NOTE: The outband LED will be off.

(2) Change the voltage-level setting so that the voltage is out of band.

NOTE: The OUTBAND LED will be turned on.

NOTE: After a 30-second time delay, the tap changer will operate.

I. Adjust the voltage-level setting so that the voltage is out of band on the other side.

(1) After 30 seconds, the tap changer will operate in the other direction.

(2) If the regulator is allowed to pass through the neutral position with each change of direction, the L and R LED's in the control can be checked visually to make sure the tap changer is operating in the proper direction.

J. With the operational check completed, return the tap changer to the neutral position.

K. Disconnect the external potential source.

L. Reconnect the internal terminal that was removed from V_2.

M. Remove the ground connection from the three high-voltage bushings.

INSTALLATION

1. Mount the regulator on a pole, crossarm, or platform.

A. A McGraw-Edison elevating structure–built to customer specifications–(Figure 8) simplifies substation installation of regulators requiring a specific bushing height.

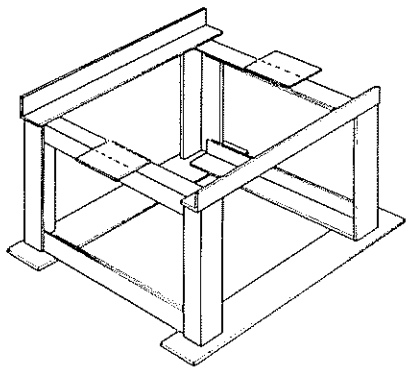


Figure 8
Substation elevating structure.

2. Mount the regulator control on the regulator tank or at a point remote from the unit.

NOTE: Rubber-covered cable is available in lengths of 15, 20, 25, 30, and 35 feet for interconnection between the control and the regulator. For information consult your McGraw-Edison representative.

3. Connect the regulator(s) on the line.

One regulator can regulate a single-phase circuit or one phase of a three-phase wye or delta circuit. Two regulators connected in open-delta, or three regulators connected in closed-delta, can regulate a three-phase, three-wire wye or delta circuit. When connected in wye, they can regulate a three-phase, four-wire multigrounded wye circuit. Three regulators cannot be connected in wye on three-phase, three-wire circuits because of a possible neutral shift. Typical connection diagrams are illustrated in Figure 7.

CAUTION

A regulator can be placed in service without interrupting load continuity; however, the regulator tap changer must be on neutral during energization. Otherwise, part of the series winding will be shorted. Always assume that a regulator is off neutral.

To connect a regulator:

A. Set the selector switch, (Figure 2) to an OFF position.

B. Close the source-load (SL) disconnect switch.

C. Close the source (S) disconnect switch.

D. Initiate the selector switch to RAISE or LOWER to operate the regulator switch mechanism to NEUTRAL.

(1) When on Neutral, the neutral lamp will light and both the L and R LED's will be off.

E. Set the selector-switch on OFF.

F. Close the load (L) disconnect switch.

G. Open the bypass switch.

H. Set the selector switch to AUTO.

I. Set the voltage-level control to call for one step of voltage correction.

(1) If satisfactory, call for one step of voltage correction in the opposite direction.

(2) If both operations are satisfactory, set the voltage-level control at the desired level.

OPERATING A REGULATOR

1. Set the desired voltage level on the control (Figure 2).

A. Determine the ratio of the regulator by dividing the rated voltage by the control volts at rated volts. Both of these factors appear on the nameplate (Figure 9).

Example: If the rated voltage = 7620 and the control volts at rated voltage = 127, the ratio = 60 (7620÷127).

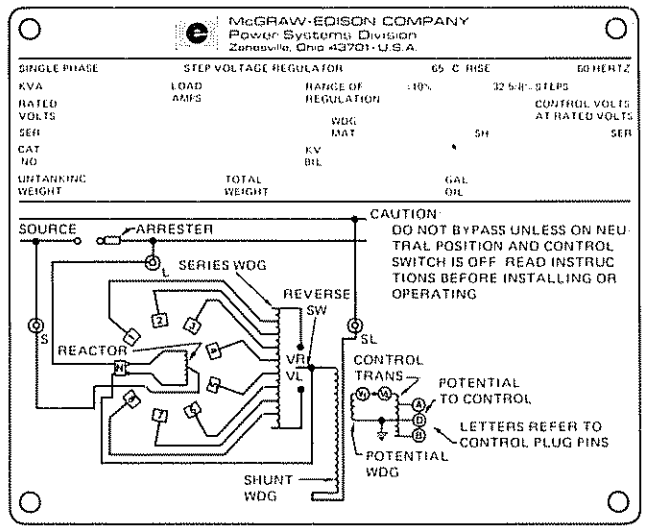


Figure 9
Simplified regulator nameplate.

B. Divide the ratio of the regulator into the voltage to be maintained at the regulator to determine the voltage-level setting.

Example: To maintain 8000 volts at a regulator that has a ratio of 60, divide 8000 by 60, 8000÷60 = 133 volts, the voltage level setting.

NOTE: When the desired voltage level is first set, the OUTBAND LED may come on.

2. Set the control switch on AUTO.

A. When the time delay has elapsed, the regulator will operate the proper number of times to bring the voltage into band.

NOTE: When the voltage is brought into band, the OUTBAND LED will go off.

(1) If the tap changer is caused to move in the direction of LOWER voltage, the L LED will go on and will remain on as long as the regulator stays on the lower side of neutral.

(2) If the tap changer is caused to move in the direction of RAISE voltage, the R LED will go on and will remain on as long as the regulator stays on the raise side of neutral.

(3) Both the L and the R LED's will be off on the neutral position and the neutral lamp on the tank will be on

3. Check the regulated output voltage.

A. Plug an a-c voltmeter (1000 ohms/volt minimum) into the control monitoring plug with the regulator in band and, neglecting possible voltmeter error, the voltage indicated should be within one volt of the control voltage-level setting.

NOTE: The time delay must be a continuous 30 seconds in order to effect a tap change. If the voltage moves in band before the 30 seconds have expired, the time delay will start over the next time the voltage goes out of band.

MAINTENANCE

Recommended maintenance includes occasional operational checks in the field and a periodic inspection of all major regulator components in a service center where untanking is practicable.

Duty and operating cycles of regulators vary depending upon their locations in the system. The number of complete inspections and the occasional operational checks should, therefore, be predicted upon the duty and operating cycles of each regulator.

REMOVING A REGULATOR FROM SERVICE

A regulator must be removed from service before performing some maintenance checks. A regulator can be removed from service without interrupting load continuity if the tap changer is on the neutral position during deenergization. **If the tap changer is not on the neutral position during deenergization, part of the series winding will be shorted.**

To remove a regulator from service:

1. Initiate the selector switch (Figure 2) to RAISE or LOWER to operate the regulator switch mechanism to neutral. On neutral, the neutral lamp will be on, and both the L and the R LED's will be off.
2. Move the selector switch to an OFF position.
3. Close the bypass switch.
4. Open the source (S) disconnect switch.
5. Open the load (L) disconnect switch.
6. Open the source-load (SL) disconnect switch.

If it is impossible to return the regulator switch mechanism to neutral:

1. Connect a fuse cutout large enough to carry the line current load across the Source (S) disconnect switch.
2. Close the fuse cutout.
3. Open the source (S) disconnect switch.
4. Close the bypass switch, (the fuse will blow).
5. Open the load (L) disconnect switch.
6. Open the source-load (SL) disconnect switch.
7. Disconnect and remove the fuse cutout.

UNTANKING A REGULATOR

An examination of internal components may indicate that the regulator needs to be untanked.

To untank a regulator:

1. Manually run the tap changer to neutral.
2. Remove the series arrester.
3. Free the tank cover by removing the clamping ring.
4. Attach a chain hoist to the lifting eyes.
5. Raise the cover—with core and coil assembly attached—approximately one foot.
6. Block the cover.
7. Disconnect the terminal plug leads at the tap changer terminal board.
8. Disconnect the neutral lamp at the lamp terminal.
9. Remove the lead ties.
10. Remove the neutral lamp holder from the tank.
11. Lift the internal assembly from the tank.

ROUTINE INSPECTIONS

1. Oil.

A. After six months, sample the oil in the regulator and perform a dielectric test in a standard test cup.

(1) If the oil tests below 24 kv, it must be filtered or replaced with new or reconditioned oil.

B. Test the oil again after one year of regulator operation.

C. Establish a schedule for sampling and testing the oil periodically.

2. Tap Changer.

Of all the components in a 32-step regulator, the tap changer (Figure 10) sustains the greatest amount of mechanical duty.

A. After four years remove the regulator from service.

(1) Appraise the condition and wear of both the movable and the stationary contacts.

(2) Set up a schedule for periodic inspection based on the appraisal.

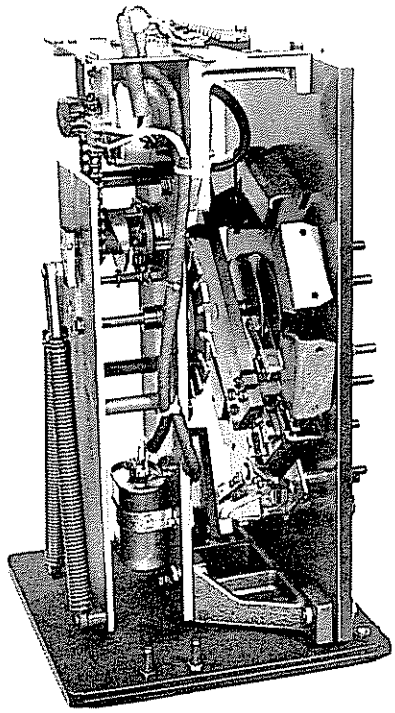


Figure 10
Tap changer.

TROUBLESHOOTING

Trouble	Cause/Correction
A regulator responds properly to MANUAL operation by turning the control switch to LOWER and RAISE, but malfunctions when the control switch is set on AUTO.	The trouble is in the control circuitry. Repair or replace the control.
A regulator does not respond to either MANUAL or AUTO operation.	The trouble is internal. It may be a faulty tap changer motor or motor capacitor or it may be in the control wiring to the tap changer (Figure 11).

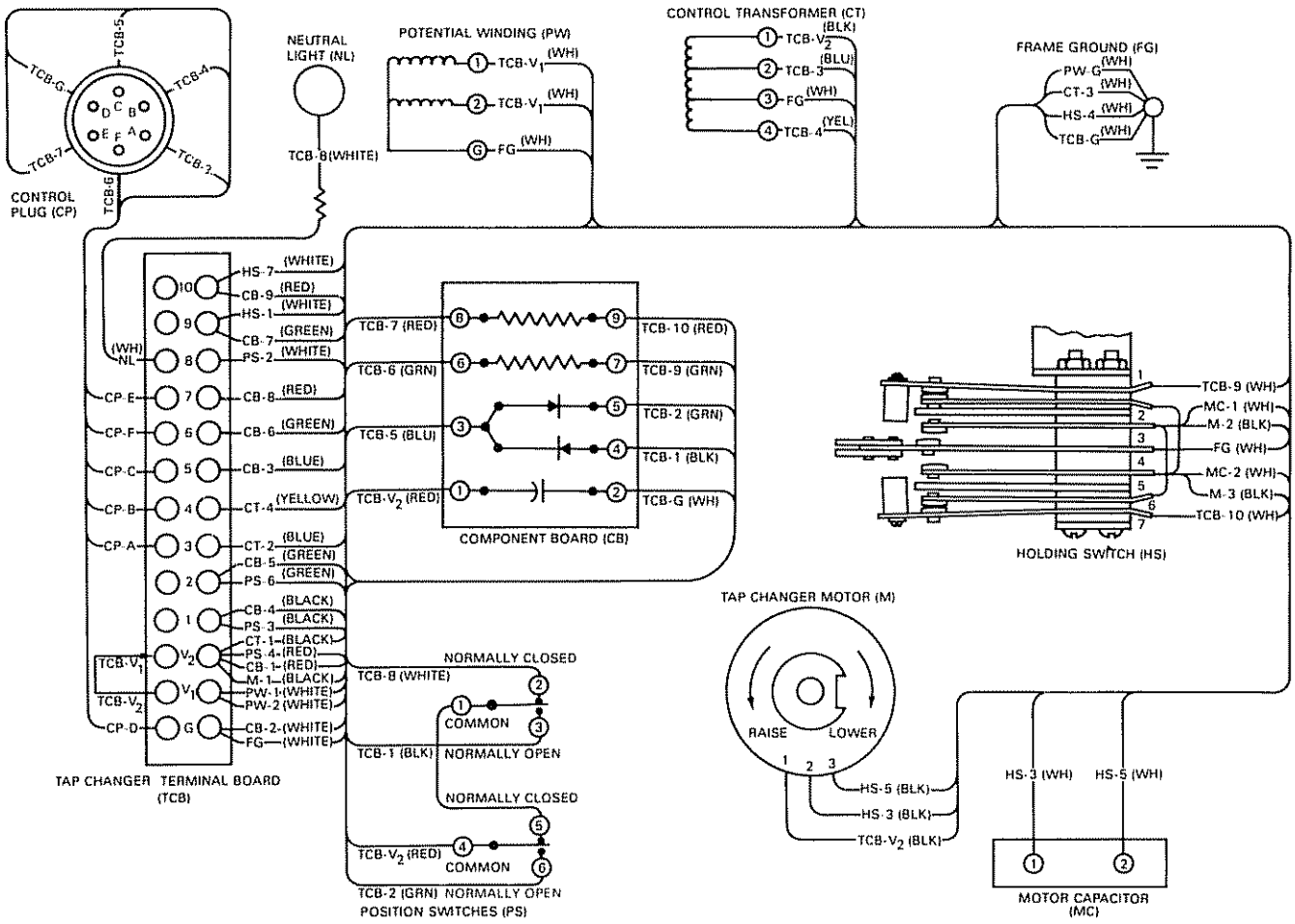


Figure 11

CONTROL SERVICING

For those utilities which are properly equipped and desire to service the simplified regulator control, the following information is provided. Figure 12 is the wiring diagram of the electronic control. Figure 14 is the voltage-sensing circuit schematic diagram. Figure 13 is the circuit board layout, and Table 2 lists and identifies the parts shown on Figure 13.

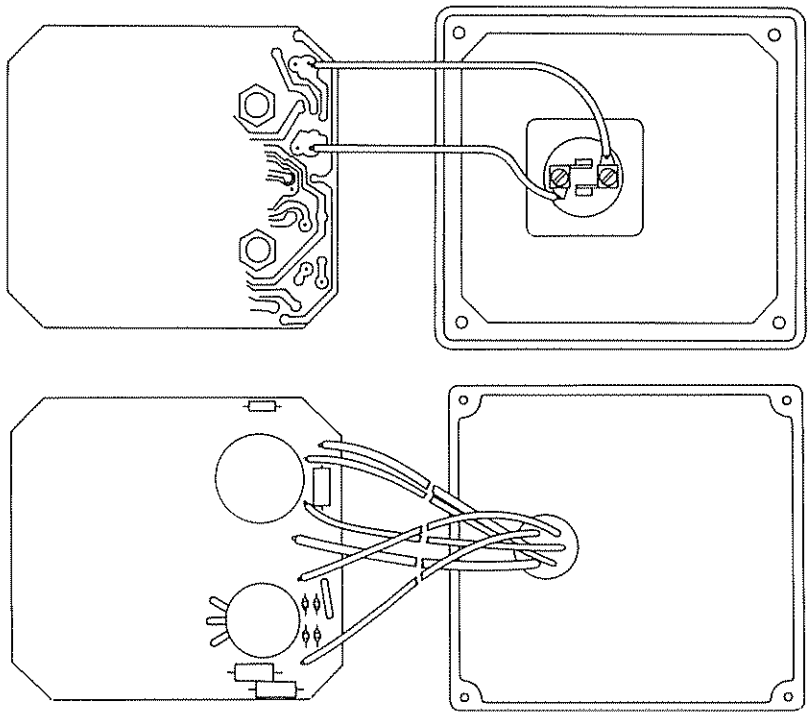


Figure 12
Electronic control wiring diagram

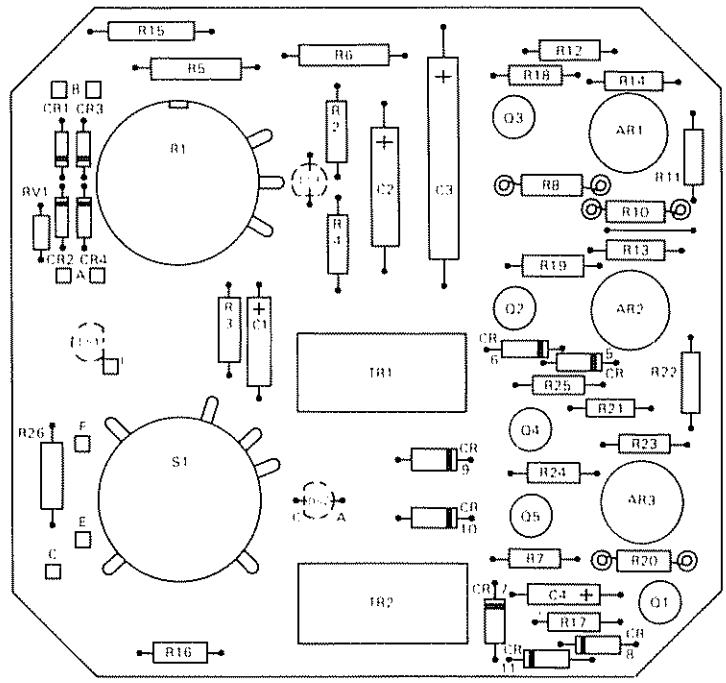


Figure 13

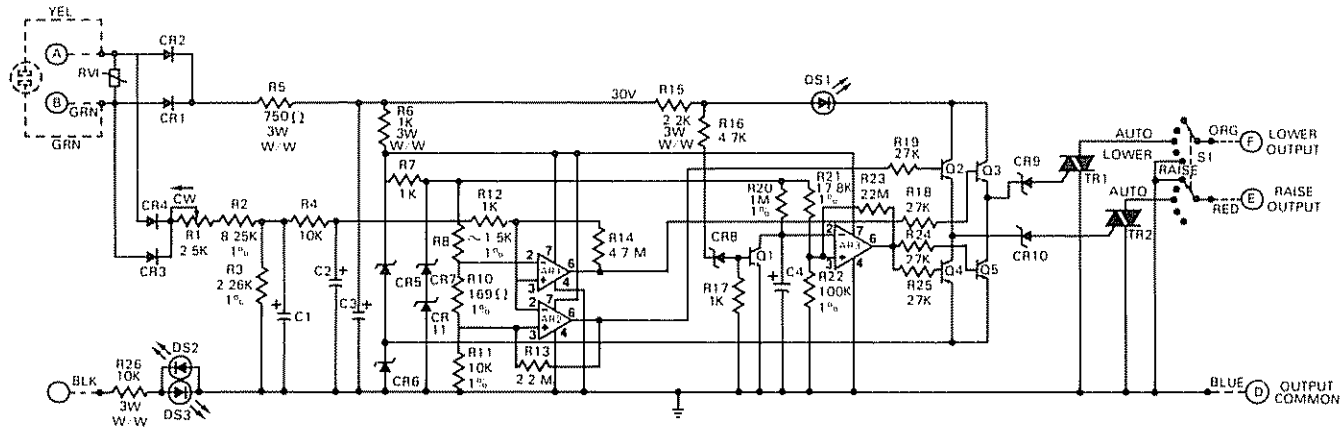


Figure 14
Voltage-sensing circuit schematic diagram

Table 2
Circuit Board Parts List

Reference	Part No.	Qty	Description	Source
AR1-AR-3	N5741T	3	741C IC, 8 pin; To-99 metal case; 0-70C	Signatics
C1	395 x 9035B2 or 475 x 9035B2	1	3.9-4.7 MF ± 10% ≥ 20 VDC; + 85 to − 50C axial lead; solid tantalum	Sprague
C2	NLW-50-50	1	50MF + 75, − 10%; 50V electrolytic	Cornell-Dubilier
C3	NLW-20-100	1	20MF +75, − 10%; 100V electrolytic	Cornell-Dubilier
C4	150D156 x 9020B2	1	15MF ±10%; 20V solid tantalum	Sprague
CR1-CR4	IN5061	4	Rectifier	
CR5 and CR8	IN759A	2	12V ±5%; 400MW Zener diode	
CR6	IN752A	1	5.6V ±5%; 400MW Zener diode	
CR7 and CR11	IN823A	2	6.2V ±5%; 400MW reference diode	Centralab
CR9 and CR10	IN753A	2	6.2V ±5%; 400MW Zener diode	
DS1-DS3	HP5082-4658	3	Light-emitting diode	Hewlett Packard
Q1-Q5	ZN1711	5	NPN signal transistor	
R1	U-0051	1	2.5K ±10%; 2W potentiometer	
R2	RN65C	1	8.25K metal film resistor	
R3	RN60C	1	2.26K metal film resistor	
R4		1	10K ±5%; 1/2W carbon film	
R5	4418	1	750 Ω ±5%; 3W wirewound	Ohmite
R6	4423	1	1K ±5%; 3W wirewound	Ohmite
R7, R12, and R17		3	1K ±5%; 1/2W carbon film	
R8		1	Factory-selected	
R10		1	169 Ω; metal film resistor	
R11		1	10K metal film resistor	
R13		1	2.2M ±5%; 1/2W carbon film	
R14		1	4.7M ±5%; 1/2W carbon film	
R15	4431	1	2.2K ±5%; 3W wirewound	Ohmite
R16		1	4.7K ±5%; 1/2W carbon film	
R18, R19, R24, and R25		4	27K ±5%; 1/2W carbon film	
R20		1	1M metal film resistor	
R21		1	17.8K metal film resistor	
R22		1	100K metal film resistor	
R23		1	22M ±5%; 1/2W carbon film	
R26		1	10K ±5%; 3W wirewound	Ohmite
RV1	V150LA10	1	120V semiconductor varistor	GE
S1		1	5-position rotary switch	
TR1 and TR2	T2311D	2	Triac; To-5; case with heat sink	RCA

NOTES

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