DESCRIPTION • INSTALLATION • OPERATION

INSTRUCTIONS

PARALLEL OPERATION

TAP-CHANGING-UNDER-LOAD TRANSFORMERS WITH STEP-BY-STEP SWITCH CONTROL

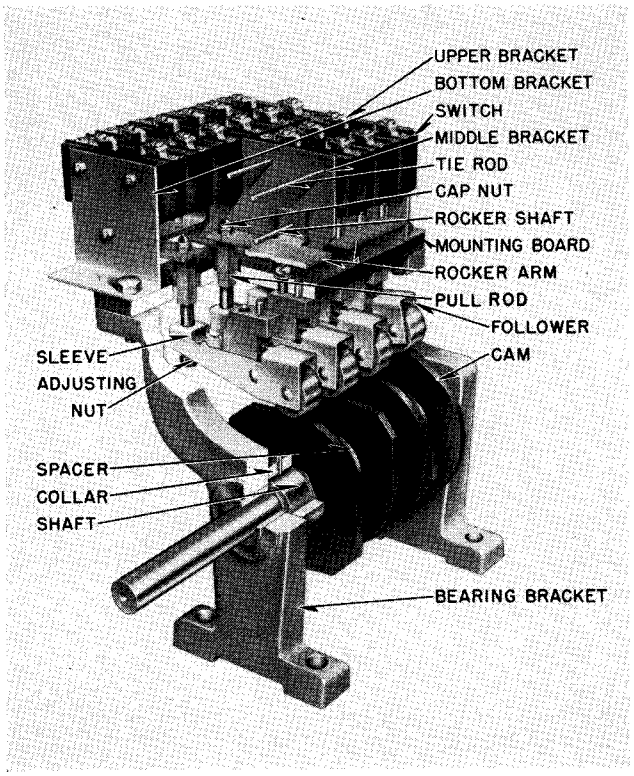


FIG. 1. Step-by-Step Switch Assembly.

WHEN TWO OR MORE transformers are connected in parallel, any difference in their voltage ratios will cause a current to circulate through the loop formed by the paralleled unit. It is, therefore, necessary that paralleled transformers have the same voltage ratio to prevent thermal overloading due to the circulating current. This requirement, as well as requirements for impedance, phase angle, and polarity are explained in Instruction Leaflet I.L. 47-600-4.

With tap-changing-under-load transformers, it is not enough that they be designed for the same voltage ratio. In addition, it is necessary that the tap changers connect to the same voltage tap; that is, the tap changers must operate together, or in step. Step-by-step switch control for parallel operation of tap changing under load operates the tap changers to meet this condition.

In step-by-step control, one unit is selected as a master unit. This unit operates in response to the conventional voltage regulating relay and line drop compensator. Its operation initiates operation of all other units paralleled with it.

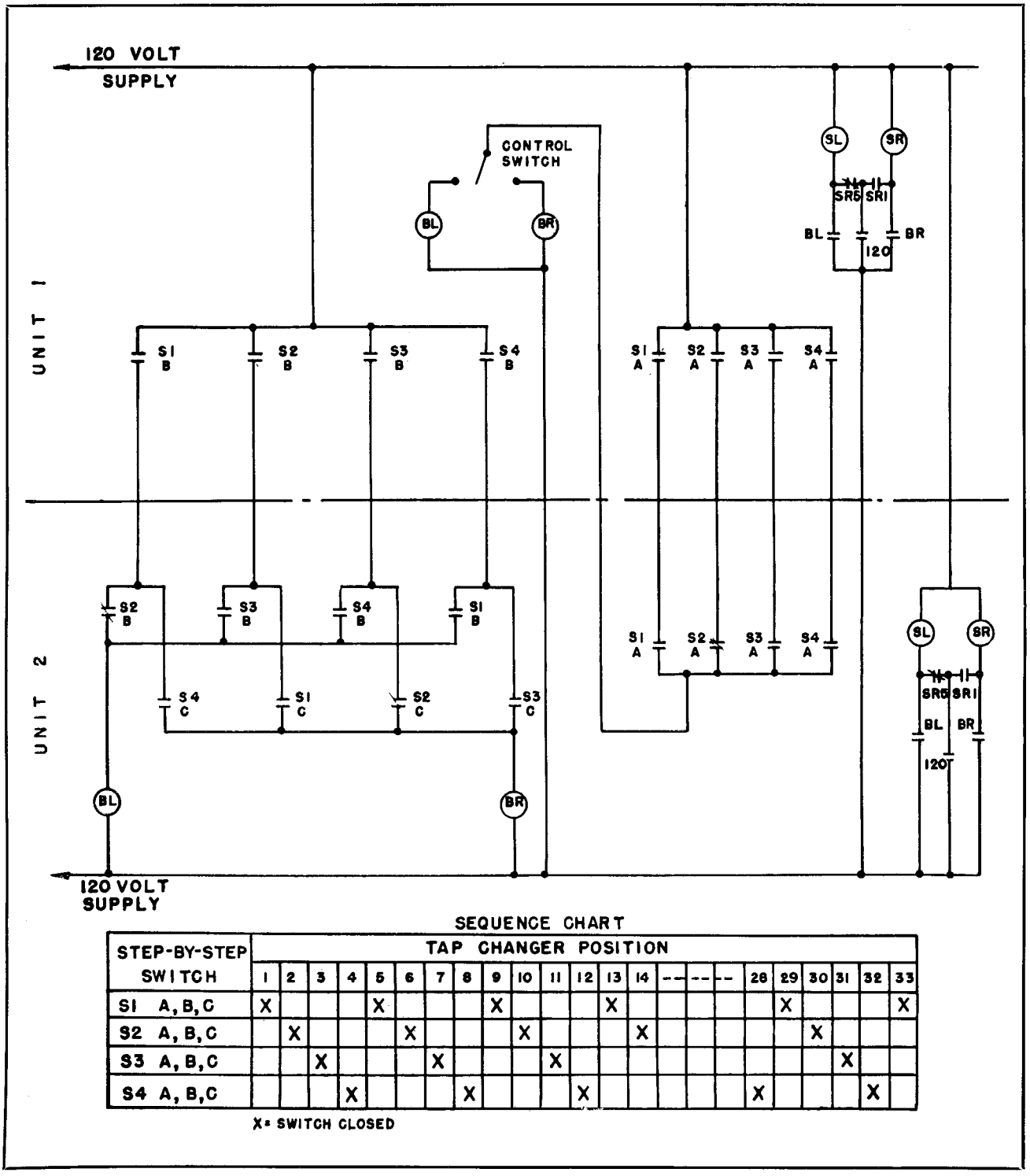
The operation of step-by-step control also provides a safety lock-out. If, because of some failure in the equipment, one tap changer fails to operate, no units will operate more than one step. This limits the circulating current to that caused by the voltage ratio difference of one step of the tap changer and thus protects against burn-out of the transformer.

DESCRIPTION

The step-by-step control works in cooperation with the standard tap changer controls, which are described in other instruction leaflets supplied with the tap changing equipment. The step-by-step control connects between the initiating circuits (that is, the manual control switch for manual control; and the voltage regulating relay, line drop compensator, and time delay relays for automatic control) and the operating circuits (that is, the motor control relays on URS tap changers and the motor starters on UNR and UT tap changers). The standard controls have all their normal functions except as limited and supplemented by the step-by-step switches.

The mechanical construction of the step-by-step switch is shown in the cutaway view of Fig. 1. It consists essentially of four groups of three switches, each group operated by a rocker arm which, in turn, is operated from a rotating cam by a pivoted cam follower and pull rod. The complete step-by-step switch assembly is mounted in the operating mechanism of the tap changer and geared to the tap changer drive shaft.

The paralleling switch is a three-position control switch for manually selecting parallel or independent operation and the master and follower units. In a bank of several units, the positions of the paralleling switch perform the following functions: The "IND" position makes the unit entirely inde-



SEQUENCE CHART

STEP-BY-STEP SWITCH	TAP CHANGER POSITION																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	--	--	--	28	29	30	31	32	33
S1 A, B, C	X				X				X				X						X				X
S2 A, B, C		X				X				X				X						X			
S3 A, B, C			X				X				X										X		
S4 A, B, C				X				X				X						X				X	

X = SWITCH CLOSED

FIG. 2. Fundamental Circuit for Step-by-Step Control.

pendent of the other units of the bank and operable in response to its own manual control switch and voltage regulating relay with no effect on the other units. The "PAR. MASTER" position makes the unit respond to its own manual control switch and voltage regulating relay and also makes it control the operation of all units which are set on "PAR. FOLLOWER". The "PAR. FOLLOWER" position makes the unit operate only in response to operation of the unit set on "PAR. MASTER".

The two auxiliary Type SG relays, S# 1008 539, provide the necessary intermediate relays between the initiating and operating circuits to permit applying step-by-step control.

INSTALLATION

The paralleling equipment is usually mounted at the factory and shipped in place on the transformer. The connections required between units are shown on the wiring diagram supplied with the transformer.

In those cases where paralleling equipment is being added in the field or where the paralleling equipment is to be mounted by the customer, outline drawings, drilling plans, and installation instruction drawings are supplied. The installation instruction drawing gives detail information regarding the location, alignment, and installation procedure for the step-by-step switch. For proper operation, the step-by-step switches must be aligned so that, starting from any position and moving in either direction toward the next position, the 120 switch will close before the step-by-step switch opens.

The paralleling switch and the auxiliary relays should be mounted on a switchboard conveniently located with respect to the other control equipment for the tap changer. The auxiliary relays are open-type construction and are intended for back-of-the panel mounting.

The relays should be mounted with their bases vertical and with the stationary contacts at the top in a location free from dirt, moisture, excessive vibration and heat.

OPERATION

For clarity in describing the fundamental operation, Fig. 2 is drawn for two units only, with unit 1 the master unit and unit 2 the follower unit. Only the circuits essential for describing the fundamental theory are shown.

Assume both tap changers are on a position where the switches S2-A, S2-B and S2-C are closed. The sequence chart shows this could be position 6, for example. Close the control switch to the left. This completes the circuit from the supply bus through S2-A of unit 1, S2-A of unit 2, and BL of unit 1 to the other side of the line.

BL of unit 1, therefore, closes its contact BL which energizes relay SL of unit 1. SL is the motor control relay which starts unit 1 operating in the lower direction. Soon after operation starts, switch 120 is mechanically operated to close its contacts, by-passing contacts BL through SR5. As operation of the tap changer continues, step-by-step switch S2-A is mechanically operated to open, de-energizing BL. However, SL is still energized through 120, so that the tap changer continues running toward position 5 until that position is reached, at which time 120 opens, de-energizing SL, and stopping the tap changer on position. As this position is approached, step-by-step switch contacts S1-A and S1-B of unit 1 close.

Therefore, we now have unit 1 on position 5 with switches S1-A and S1-B closed and unit 2 on position 6 with S2-A, S2-B, and S2-C closed.

Thus the circuit to both BR and BL of unit 1 is open. Therefore, operation of the control switch in either direction will not cause any further operation of unit 1.

But there is now a circuit from the 120 volt supply through S1B of unit 1 and S2B of unit 2 to BL of unit 2 and to the other side of the supply. Therefore, BL of unit 2 is energized, closing contact BL and operating unit 2 in the lower direction. Switch 120 closes and seals SL. The operation of the tap changer opens S2-B, de-energizing BL, but SL is still energized through 120. As position 5 is reached, S1-A, S1-B, and S1-C of unit 2 close and 120 opens, de-energizing SL and stopping the tap changer on position.

Therefore, we now have both unit 1 and unit 2 on position 5. The circuit for BR and BL of unit 1 is now re-established so that the control switch is again operative. The circuits to BR and BL of unit 2 are open so that unit will make no further operations.

For operation in the raise direction, a similar sequence takes place as given below in outline form for operating from position 6 to position 7.

Turn control switch to the right.
BR is energized on unit 1.
Contacts BR close on unit 1.
SR is energized on unit 1.
SR1 closes and SR5 opens on unit 1.
Units 1 starts to operate.
120 closes on unit 1.
S2-A opens on unit 1.
BR is de-energized on unit 1.
BR contacts open on unit 1.
Unit 1 approaches position 7.
S3-A and S3-B close on unit 1.
120 opens on unit 1.
Unit 1 stops on position 7.
BR of unit 2 is energized through S3-B of unit 1 and S2-C of unit 2.
Contacts BR close on unit 2.
SR is energized on unit 2.
SR1 closes and SR-5 opens on unit 2.
Unit 2 starts to operate.
120 closes on unit 2.

PS17, inclusive, by-passing the SA switches; and closes contacts PS11 to permit operation as required by the initiating circuits. The "IND" position of the paralleling switch, therefore, makes its unit responsive to its own control only, and its operation has no affect on the control of the other units nor is its control affected by the operation of the other units. The "IND" position is useful (a) for removing a unit from the bank for maintenance or servicing; (b) for separating a section of the load bus and regulating it separately; (c) for using a single unit by itself.

The initiating circuits of Fig. 3 may be any of the conventional manual or automatic controls. Since, on the follower units, both PS12 and PS13 are open, the operation of the initiating circuits on these units cannot operate the tap changers. On many tap changers having automatic control, the voltage regulating relay and the control and operating circuits have separate voltage supplies and separate circuit breakers or knife switches. In these cases, the operation of the initiating circuits on the follower units can be stopped, if desired, by opening the breaker or switch in the voltage regulating relay circuit. This will, of course, save some contact burning and some wear in these parts and for that reason is recommended, but it is not necessary since the initiating circuits are all designed for continuous operation.

ADJUSTMENT, MAINTENANCE AND INSPECTION

When step-by-step control is installed at the factory all initial adjustments are made before shipment.

When step-by-step control is installed in the field, the cams should be adjusted so that, starting from any tap changer position and moving in either direction, the step-by-step switch will remain closed until after the 120 switch opens.

It is recommended that when paralleling equipment is being installed, the entire tap changer and its control be carefully checked and adjusted according to the instructions furnished with the tap changer. As has been explained, in step-by-step paralleling control, each tap changer seals in individually and completes the tap change under the control of its own motor control relays and 120 switch. The controls on each unit must, therefore, operate properly, the same as though the units were operating separately, if proper parallel operation is to be obtained.

After the initial adjustment has been made, the only maintenance required is occasionally blowing accumulated dust from the relays and paralleling switch, also occasionally inspecting the relay and paralleling switch contacts. An occasional drop of light machine oil on the roller shaft of each cam follower, on the rocker arm pivots, and on the pull rod bearings of the step-by-step switch is recommended, but excessive oiling should be avoided to prevent collecting dirt and grit.

REPAIR PARTS

Order renewal parts from the nearest Westinghouse Office, or from the Sharon, Pa., Plant, giving serial number, type, and S.O. or style numbers stamped on the main transformer nameplate and a complete description of the parts required.

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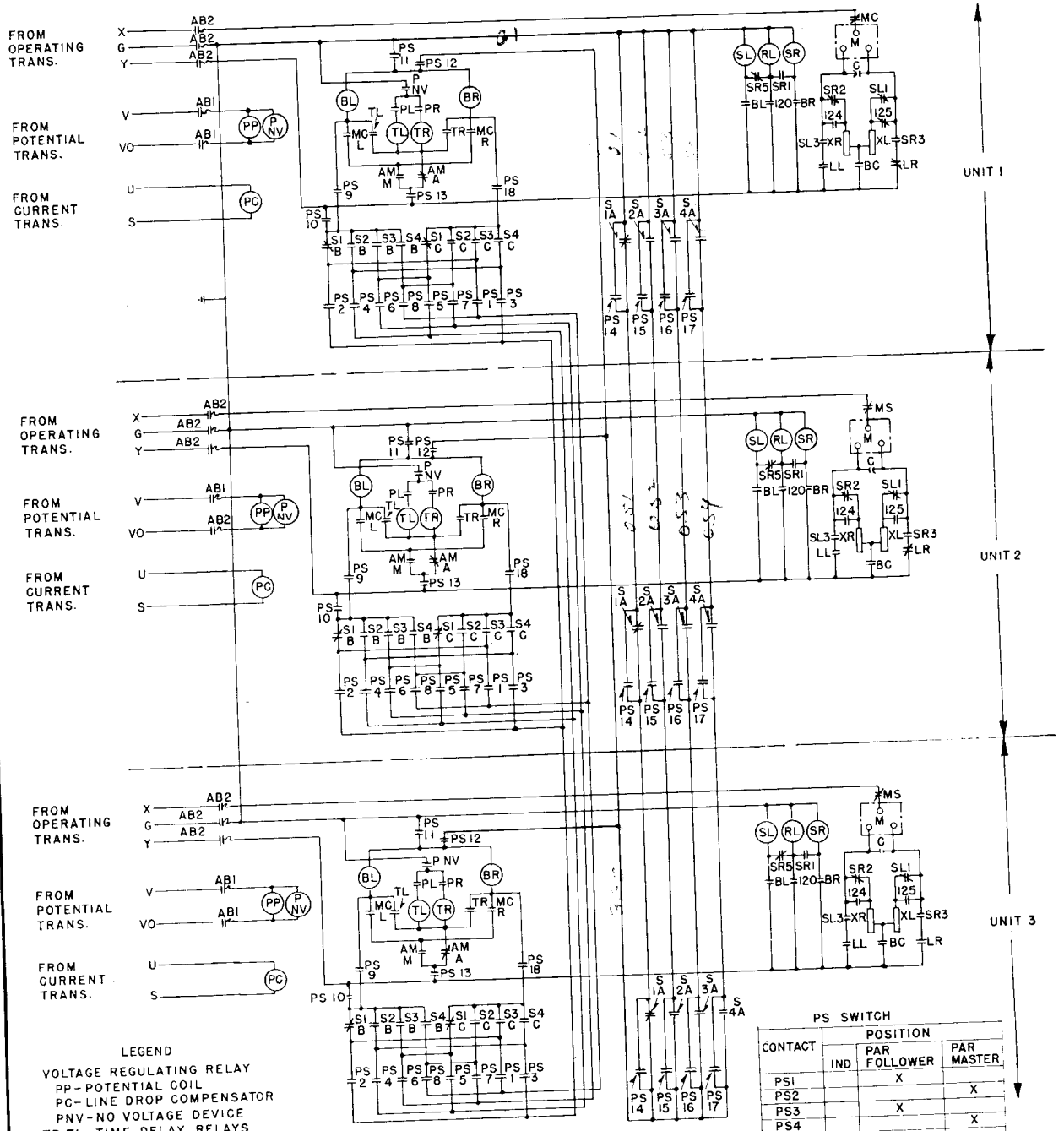
PARALLEL OPERATION



PS SWITCH

CONTACT	POSITION IND	PAR FOLLOWER	PAR MASTER
PS1		X	
PS2			X
PS3		X	
PS4			X
PS5		X	
PS6			X
PS7		X	
PS8			X
PS9		X	
PS10			X
PS11	X	X	
PS12			X
PS13	X		X
PS14	X		
PS15	X		
PS16	X		
PS17	X		
PS18		X	

FIG. 3. Schematic Diagram of Step-by-Step Control.

S2-C opens on unit 2.
BR is de-energized on unit 2.
BR contacts open on unit 2.
Unit 2 approaches position 7.
S3A, S3-B and S3-C close on unit 2.
120 opens on unit 2.
Unit 2 stops on position 7.

The purpose of normally closed contact, SR5, can best be explained by an example. Suppose, first, that during the operation of unit 1, the power supply fails. Then all relays will be de-energized with the tap changer between positions, so that switch 120 is closed. Immediately when power is restored, the circuit is established through 120 and SR5 to SL to immediately operate the tap changer to the next lower position. If the tap changer were operating in the "lower" direction when the power failure occurred, this completes the operation as started and sets up the circuit to operate the follower unit. If the tap changer was operating in the "raise" direction, this returns it to the position from which it started and re-establishes the circuit through the S-A switches so that the tap changer can be operated by the control switch.

Suppose, secondly, that the power supply fails during the operation of unit 2, stopping it between positions. Immediately when power is restored, the circuit is established through 120 and SR5 to SL to immediately operate the tap changer to the next lower position. If the tap changer were operating in the "lower" direction, this completes the operation. If the tap changer were operating in the "raise" direction, the closing of the SC switches as it returns to the next lower position immediately energizes BR and the tap changer is then operated a step in the "raise" direction to complete the action which was in progress when the power failure occurred. Without SR5, a power failure during operation would result in lock-out. With SR5, the tap changers will either complete the operation as started or return to the starting point immediately upon restoration of the power supply.

Several features of the operation, described above, should be especially noted:

1. The master unit cannot operate unless all tap changers are on corresponding positions.

2. As soon as the master unit moves far enough to close its 120 switch, the remainder of the operation of both units is controlled by mechanically operated switches and is not dependent upon relay sealing circuits.

3. There is no critical relay timing. Upon completion of operation of unit 1, the circuit to BR or BL of unit 2 is maintained until opened by the operation of unit 2.

4. After operation is started, each unit individually, whether master or follower, is sealed in during operation and stopped on the next position by its own 120 switch.

In Fig. 3, the fundamental circuit of Fig. 2 is shown in its practical form as applied on three tap changers. Note that all units are identical so that the figure may be reduced to two units or increased to any greater number by simply subtracting or adding identical units. The parts of Fig. 3, which appeared in Fig. 2, are identified by the same symbols. Therefore, the operation can be followed on Fig. 3 by referring to the sequences given for Fig. 2, as the additional equipment of Fig. 3 provides functions as described below but does not change those already described.

In Fig. 3, all units are made identical so that any unit may be selected as the master unit, any unit may be operated independently, and each unit is complete in itself and may be moved to another point in the system and operated by itself. This is accomplished by including the S-A, S-B, and S-C switches in all units, even though for parallel operation only S-A and S-B are used in the master unit; by including complete initiating circuits in each unit, even though for parallel operation they are used in only the master unit; and by including a three position paralleling switch to select the operating status of each unit.

The paralleling switch contact sequence is shown in the chart in Fig. 3. The contacts 1 to 8, inclusive, make the connections from the step-by-step switches to the buses between units. On the master unit, the even numbered contacts connect the step-by-step switches to the bus. On the follower units, the odd numbered contacts connect the step-by-step switches to the buses. Contacts PS9 and PS18 disconnect the B and C step-by-step switches from BL and BR of the master unit and make these connections on the follower units, while PS10 connects the B step-by-step switches of the master unit to the 120 volt supply. Tracing these connections in Fig. 3 will show that they are exactly the same as the simplified circuit of Fig. 2.

To complete the initiating circuit of the master unit, contacts PS12 and PS13 are closed on that unit only.

The third position of the paralleling switch, the independent position opens contacts PS1 to PS10 and PS12 and PS18, inclusive, completely isolating the SB and SC switches; closes contacts PS14 to

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TAP-CHANGING-UNDER-LOAD TRANSFORMERS WITH STEP-BY-STEP SWITCH CONTROL

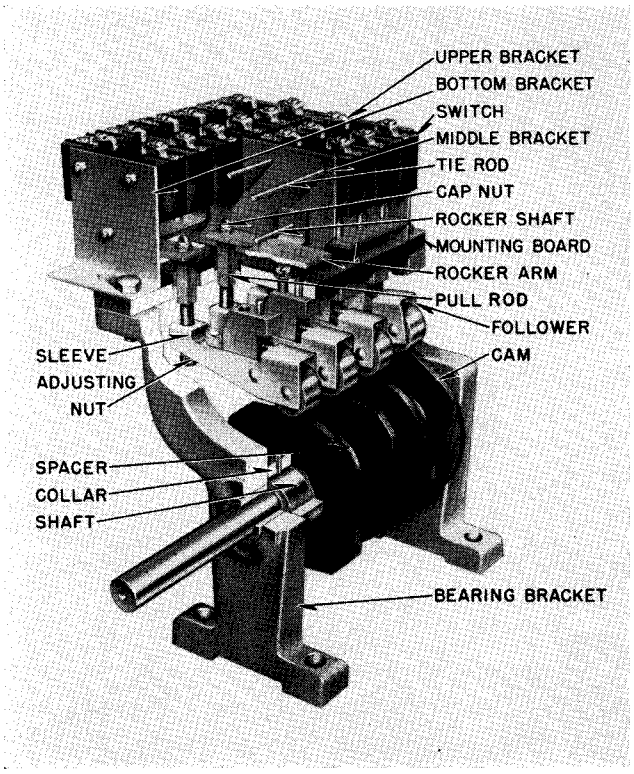


FIG. 1. Step-by-Step Switch Assembly.

WHEN TWO OR MORE transformers are connected in parallel, any difference in their voltage ratios will cause a current to circulate through the loop formed by the paralleled unit. It is, therefore, necessary that paralleled transformers have the same voltage ratio to prevent thermal overloading due to the circulating current. This requirement, as well as requirements for impedance, phase angle, and polarity are explained in Instruction Leaflet I.L. 47-600-4.

With tap-changing-under-load transformers, it is not enough that they be designed for the same voltage ratio. In addition, it is necessary that the tap changers connect to the same voltage tap; that is, the tap changers must operate together, or in step. Step-by-step switch control for parallel operation of tap changing under load operates the tap changers to meet this condition.

In step-by-step control, one unit is selected as a master unit. This unit operates in response to the conventional voltage regulating relay and line drop compensator. Its operation initiates operation of all other units paralleled with it.

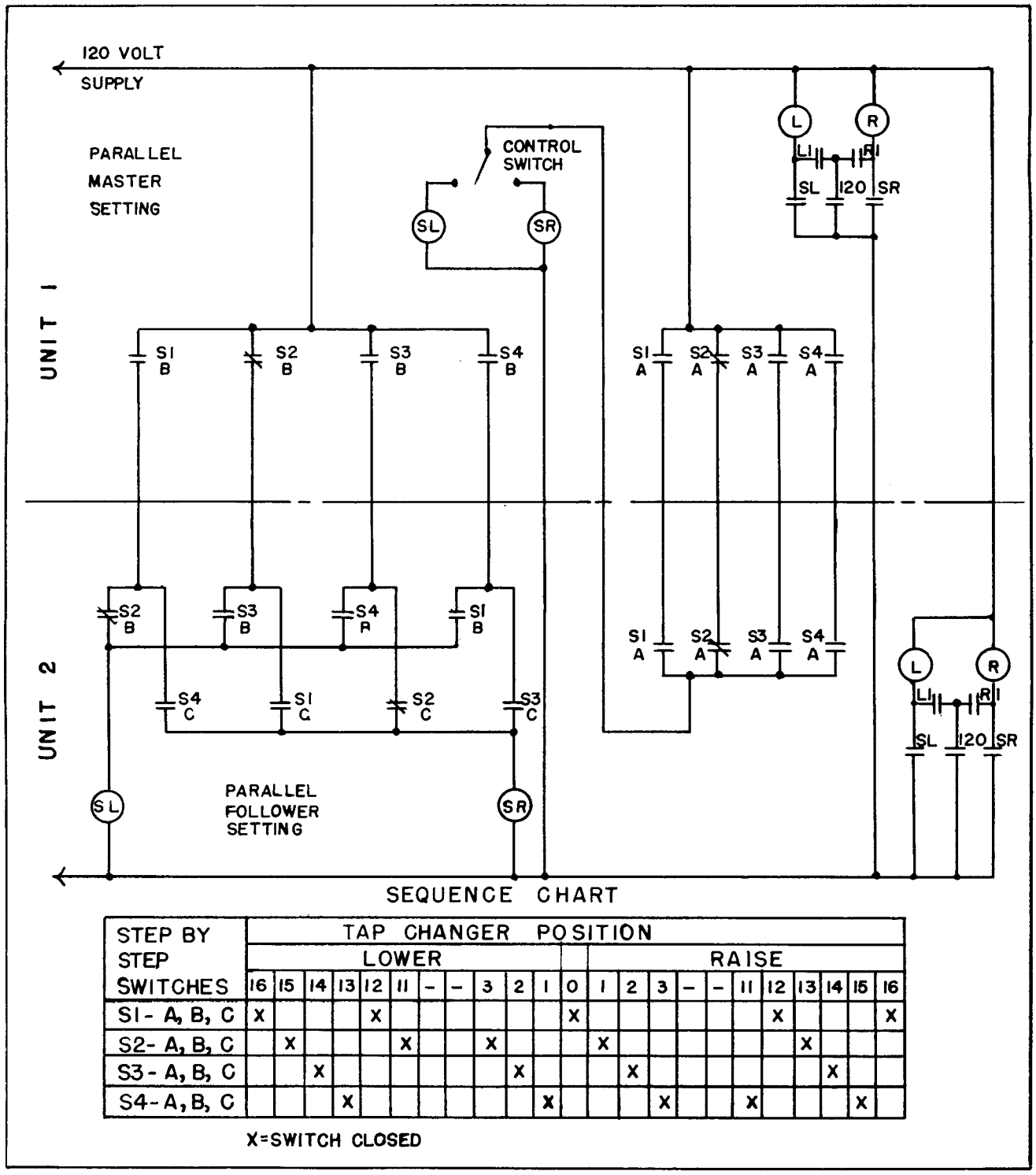
The operation of step-by-step control also provides a safety lock-out. If, because of some failure in the equipment, one tap changer fails to operate, no units will operate more than one step. This limits the circulating current to that caused by the voltage ratio difference of one step of the tap changer and thus protects against burn-out of the transformer.

DESCRIPTION

The step-by-step control works in cooperation with the standard tap changer controls, which are described in other instruction leaflets supplied with the tap changing equipment. The step-by-step control connects between the initiating circuits (that is, the manual control switch for manual control; and the voltage regulating relay, line drop compensator, and time delay relays for automatic control) and the operating circuits (that is, the motor control relays on URS tap changers and the motor starters on UNR and UT tap changers). The standard controls have all their normal functions except as limited and supplemented by the step-by-step switches.

The mechanical construction of the step-by-step switch is shown in the cutaway view of Fig. 1. It consists essentially of four groups of three switches, each group operated by a rocker arm which, in turn, is operated from a rotating cam by a pivoted cam follower and pull rod. The complete step-by-step switch assembly is mounted in the operating mechanism of the tap changer and geared to the tap changer drive shaft.

The paralleling switch is a three-position control switch for manually selecting parallel or independent operation and the master and follower units. In a bank of several units, the positions of the paralleling switch perform the following functions: The "IND" position makes the unit entirely inde-



SEQUENCE CHART

STEP BY STEP SWITCHES	TAP CHANGER POSITION																					
	LOWER											RAISE										
	16	15	14	13	12	11	-	-	3	2	1	0	1	2	3	-	-	11	12	13	14	15	16
S1 - A, B, C	X				X							X							X				X
S2 - A, B, C		X				X			X				X							X			
S3 - A, B, C			X							X				X							X		
S4 - A, B, C				X							X				X			X				X	

X=SWITCH CLOSED

FIG. 2. Fundamental Circuit for Step-by-Step Control.

pendent of the other units of the bank and operable in response to its own manual control switch and voltage regulating relay with no effect on the other units. The "PAR. MASTER" position makes the unit respond to its own manual control switch and voltage regulating relay and also makes it control the operation of all units which are set on "PAR. FOLLOWER". The "PAR. FOLLOWER" position makes the unit operate only in response to operation of the unit set on "PAR. MASTER".

INSTALLATION

The paralleling equipment is usually mounted at the factory and shipped in place on the transformer. The connections required between units are shown on the wiring diagram supplied with the transformer.

In those cases where paralleling equipment is being added in the field or where the paralleling equipment is to be mounted by the customer, outline drawings, drilling plans, and installation instruction drawings are supplied. The installation instruction drawing gives detail information regarding the location, alignment, and installation procedure for the step-by-step switch. For proper operation, the step-by-step switches must be aligned so that, starting from any position and moving in either direction toward the next position, the 120 switch will close before the step-by-step switch opens.

The paralleling switch and the auxiliary relays should be mounted on a switchboard conveniently located with respect to the other control equipment for the tap changer. The auxiliary relays are open-type construction and are intended for back-of-the panel mounting.

The relays should be mounted with their bases vertical and with the stationary contacts at the top in a location free from dirt, moisture, excessive vibration and heat.

OPERATION

For clarity in describing the fundamental operation, Fig. 2 is drawn for two units only, with unit 1 the master unit and unit 2 the follower unit. Only the circuits essential for describing the fundamental theory are shown.

Assume both tap changers are on a position where the switches S2-A, S2-B and S2-C are closed. The sequence chart shows this could be position 11 lower, for example. Close the control switch to the left: This completes the circuit from the supply bus through S2-A of unit 1, S2-A of unit 2, and SL of unit 1 to the other side of the line.

SL of unit 1, therefore, closes its contact SL which energizes relay L of unit 1. SL is the motor control relay which starts unit 1 operating in the lower direction. Soon after operation starts, switch 120 is mechanically operated to close its contacts, by-passing contacts SL through L1. As operation of the tap changer continues, step-by-step switch S2-A is mechanically operated to open, de-energizing SL. However, L is still energized through 120, so that the tap changer continues running toward position 12 Lower until that position is reached, at which time 120 opens, de-energizing L, and stopping the tap changer on position. As this position is approached, step-by-step switch contacts S1-A and S1-B of unit 1 close.

Therefore, we now have unit 1 on position 12 Lower with switches S1-A and S1-B closed and unit 2 on position 11 Lower with S2-A, S2-B, and S2-C closed.

Thus the circuit to both SR and SL of unit 1 is open. Therefore, operation of the control switch in either direction will not cause any further operation of unit 1.

But there is now a circuit from the 120 volt supply through S1B of unit 1 and S2B of unit 2 to SL of unit 2 and to the other side of the supply. Therefore, SL of unit 2 is energized, closing contact SL and operating unit 2 in the lower direction. Switch 120 closes and seals L. The operation of the tap changer opens S2-B, de-energizing SL, but L is still energized through 120. As position 12 Lower is reached, S1-A, S1-B, and S1-C of unit 2 close and 120 opens, de-energizing L and stopping the tap changer on position.

Therefore, we now have both unit 1 and unit 2 on position 12 Lower. The circuit for SR and SL of unit 1 is now re-established so that the control switch is again operative. The circuits to SR and SL of unit 2 are open so that unit will make no further operations.

For operation in the raise direction, a similar sequence takes place as given below in outline form for operating from position 11 Lower to position 10 Lower.

Turn control switch to the right.
SR is energized on unit 1.
Contacts SR close on unit 1.
R is energized on unit 1.
R1 and R2 closes on unit 1.
Unit 1 starts to operate.
120 closes on unit 1.
S2-A opens on unit 1.
SR is de-energized on unit 1.
SR contacts open on unit 1.
Unit 1 approaches position 10 Lower.
S3-A and S3-B close on unit 1.
120 opens on unit 1.
Unit 1 stops on position 10 Lower.
SR of unit 2 is energized through S3-B of unit 1 and S2-C of unit 2.
Contacts SR close on unit 2.
R is energized on unit 2.

ADJUSTMENT, MAINTENANCE AND INSPECTION

When step-by-step control is installed at the factory all initial adjustments are made before shipment.

When step-by-step control is installed in the field, the cams should be adjusted so that, starting from any tap changer position and moving in either direction, the step-by-step switch will remain closed until after the 120 switch opens.

It is recommended that when paralleling equipment is being installed, the entire tap changer and its control be carefully checked and adjusted according to the instructions furnished with the tap changer. As has been explained, in step-by-step paralleling control, each tap changer seals in individually and completes the tap change under the control of its own motor control relays and 120 switch. The controls on each unit must, therefore, operate properly, the same as though the units were operating separately, if proper parallel operation is to be obtained.

After the initial adjustment has been made, the only maintenance required is occasionally blowing accumulated dust from the relays and paralleling switch, also occasionally inspecting the relay and paralleling switch contacts. An occasional drop of light machine oil on the roller shaft of each cam follower, on the rocker arm pivots, and on the pull rod bearings of the step-by-step switch is recommended, but excessive oiling should be avoided to prevent collecting dirt and grit.

Setting Units For Parallel Operation. When it is desired to switch into parallel two or more units which are equipped with step-by-step switches and which have been wired as per the paralleling wiring diagram furnished with the units, the following procedure is recommended:

1. Turn the automatic-manual switches of all units to the "manual" setting.

2. Operate all units to the same position with the individual unit manual control switches.

3. Turn the PS switch on one unit to the "parallel master" setting and turn the PS switch of all remaining units to the "parallel follower" setting.

4. Turn the automatic-manual switch of the "parallel-master" unit to the automatic setting.

The bank of units are now operating in parallel in response to the voltage regulating control of the "parallel-master" unit.

To Remove Units From Parallel Bank Operation. To return a number of units operating in parallel with step-by-step switches to independent operation, the following procedure is recommended:

1. Turn the automatic-manual switch of the "parallel-master" unit to the manual setting.

2. Turn the PS switch of all units to the "independent" setting.

3. Turn the automatic-manual switches of all units to the automatic setting.

Each of the units are now operating independently in response to their individual voltage regulating controls.

REPAIR PARTS

Order renewal parts from the nearest Westinghouse Office, or from the Sharon, Pa., Plant, giving serial number, type, and S.O. or style numbers stamped on the main transformer nameplate and a complete description of the parts required.

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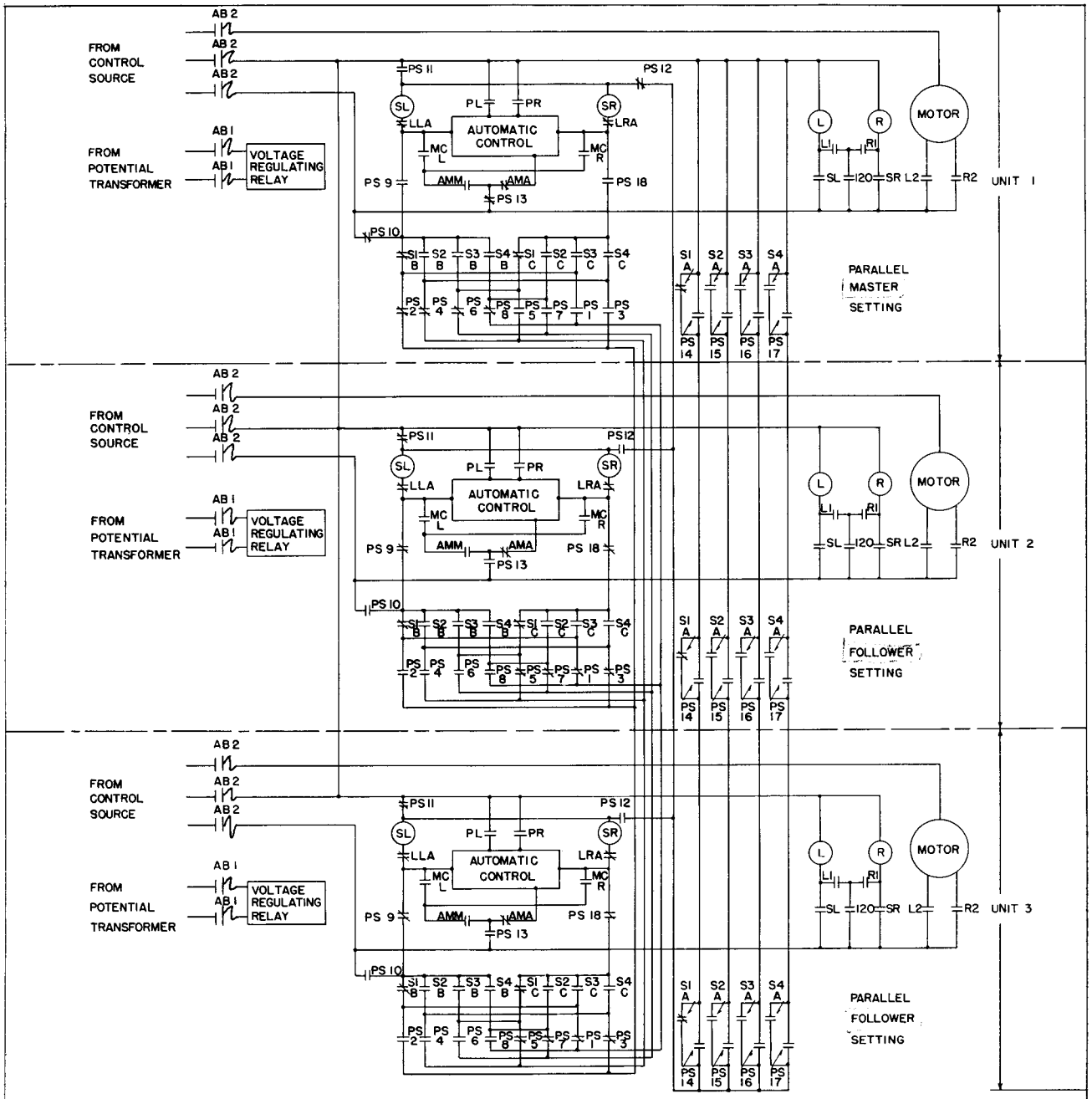

LEGEND

AM-AUTOMATIC MANUAL SELECTOR SWITCH
MC-MANUAL CONTROL SWITCH
PS-PARALLELING SWITCH
SA-,SB-,SC-,-STEP BY STEP SWITCHES
120-PILOT SWITCH
SR-,SL-CONTROL RELAYS
LLA-, LRA-AUXILIARY LIMIT SWITCHES
R-L-MOTOR CONTROL RELAYS

X=CONTACTS CLOSED

PS SWITCH

CONTACT	POSITION		
	IND	PAR FOLLOWER	PAR MASTER
PS 1		X	
PS 2			X
PS 3		X	
PS 4			X
PS 5		X	
PS 6			X
PS 7		X	
PS 8			X
PS 9		X	
PS 10			X
PS 11	X	X	
PS 12			X
PS 13	X		X
PS 14	X		
PS 15	X		
PS 16	X		
PS 17	X		
PS 18		X	

FIG. 3. Schematic Diagram of Step-by-Step Control.

R1, R2 closes on unit 2.
Unit 2 starts to operate.
120 closes on unit 2.
S2-C opens on unit 2.
SR is de-energized on unit 2.
SR contacts open on unit 2.
Unit 2 approaches position 10 Lower.
S3A, S3-B and S3-C close on unit 2.
120 opens on unit 2.
Unit 2 stops on position 10 Lower.

Several features of the operation, described above, should be especially noted:

1. The master unit cannot operate unless all tap changers are on corresponding positions.

2. As soon as the master unit moves far enough to close its 120 switch, the remainder of the operation of both units is controlled by mechanically operated switches and is not dependent upon relay sealing circuits.

3. There is no critical relay timing. Upon completion of operation of unit 1, the circuit to SR or SL of unit 2 is maintained until opened by the operation of unit 2.

4. After operation is started, each unit individually, whether master or follower, is sealed in during operation and stopped on the next position by its own 120 switch.

In Fig. 3, the fundamental circuit of Fig. 2 is shown in its practical form as applied on three tap changers. Note that all units are identical so that the figure may be reduced to two units or increased to any greater number by simply subtracting or adding identical units. The parts of Fig. 3, which appeared in Fig. 2, are identified by the same symbols. Therefore, the operation can be followed on Fig. 3 by referring to the sequences given for Fig. 2, as the additional equipment of Fig. 3 provides functions as described below but does not change those already described.

In Fig. 3, all units are made identical so that any unit may be selected as the master unit, any unit may be operated independently, and each unit is complete in itself and may be moved to another point in the system and operated by itself. This is accomplished by including the S-A, S-B, and S-C switches in all units, even though for parallel operation only S-A and S-B are used in the master unit; by including complete initiating circuits in each unit, even though for parallel operation they are used in only the master unit; and by including a three position paralleling switch to select the operating status of each unit.

The paralleling switch contact sequence is shown in the chart in Fig. 3. The contacts 1 to 8, inclusive, make the connections from the step-by-step switches to the buses between units. On the master unit, the even numbered contacts connect the step-by-step switches to the bus. On the follower units, the odd numbered contacts connect the step-by-step switches to the buses. Contacts PS9 and PS18 disconnect the B and C step-by-step switches from SL and SR of the master unit and make these connections on the follower units, while PS10 connects the B step-by-step switches of the master unit to the 120 volt supply. Tracing these connections in Fig. 3 will show that they are exactly the same as the simplified circuit of Fig. 2.

To complete the initiating circuit of the master unit, contacts PS12 and PS13 are closed on that unit only.

The third position of the paralleling switch, the independent position opens contacts PS1 to PS10 and PS12 and PS18, inclusive, completely isolating the SB and SC switches; closes contacts PS14 to PS17, inclusive, by-passing the SA switches; and closes contacts PS11 to permit operation as required by the initiating circuits. The "IND" position of the paralleling switch, therefore, makes its unit responsive to its own control only, and its operation has no affect on the control of the other units nor is its control affected by the operation of the other units. The "IND" position is useful (a) for removing a unit from the bank for maintenance or servicing; (b) for separating a section of the load bus and regulating it separately; (c) for using a single unit by itself.

The initiating circuits of Fig. 3 may be any of the conventional manual or automatic controls. Since, on the follower units, both PS12 and PS13 are open, the operation of the initiating circuits on these units cannot operate the tap changers. On many tap changers having automatic control, the voltage regulating relay and the control and operating circuits have separate voltage supplies and separate circuit breakers or knife switches. In these cases, the operation of the initiating circuits on the follower units can be stopped, if desired, by opening the breaker or switch in the voltage regulating relay circuit. This will, of course, save some contact burning and some wear in these parts and for that reason is recommended, but it is not necessary since the initiating circuits are all designed for continuous operation.