DESCRIPTION • INSTALLATION • OPERATION

INSTRUCTIONS

PARALLEL OPERATION OF LOAD TAP CHANGERS

Sequential • Out-of-Step • 3 Position Switch

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 units. 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, at any given time, connect to the same voltage tap; that is, the tap changers must operate together, or in step. Out-of-step switch control for parallel operation of tap-changing-under-load operates the tap changers to meet this condition.

Out-of-step switch control also provides a safety feature. If, because of some failure in the equipment one tap changer does not operate with the others, a lock-out is provided at the first step of separation. 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 out-of-step switch control works in cooperation with the standard tap changer controls, which are described in other instruction leaflets supplied with the tap changer equipment. The out-of-step switch circuits connect 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 UR and URS tap changers; and the motor starters on UNR, URT, and UT tap changers). The standard controls have all their normal functions, except as limited by the out-of-step switches.

The out-of-step switch is mechanically operated through suitable gears and shafts from the tap changer operating mechanism in which it is mounted. Two contact sequences are used as indicated by the following table:

Tap Changer Position		16-L	15-L	14-L	13-L	12-L	11-L	—
Out-of-Step Switch Closed	Type 1	OS1	OS2	OS1	OS2	OS1	OS2	—
	Type 2	OS1	OS2	OS3	OS4	OS1	OS2	—

Type 1 out-of-step switch is used on tap changers designed for operation in a fixed number of steps. Type 2 out-of-step switch is used on tap changers designed to operate either bridging or non-bridging as selected by the operator.

Type 2 switch can be used in place of a Type 1 by wiring contacts OS1 and OS3 and contacts OS2 and OS4 in parallel, and this is sometimes necessary either as a manufacturing expedient or to permit paralleling a new tap changer with an old tap changer designed on a different basis. In all such cases, the connections are shown in detail on the wiring diagram supplied with the equipment.

Mechanically, design details of the out-of-step switch depend upon the tap changer. On most tap changers, the out-of-step switch is constructed of cam operated control switches. On some UNR tap changers, the out-of-step switch consists of stationary fingers to which connections are made by a rotating knobbed drum.

In addition to the out-of-step switch, the following items are also used:

One paralleling switch.

Three auxiliary relays, Type SG.

One cam operated pilot switch (122) and two cam operated limit switches (LRA) and (LLA).

The paralleling switch has three positions—Parallel Master, Parallel Follower, and Independent. This enables the selection of the master unit, operation of all units independently or operating any two or more units in parallel with one or more units by-passed for independent or stand by operation.

The two auxiliary relays provide the intermediate relaying stage required between the initiating and the operating circuits to permit connecting the out-of-step switch control.

The other auxiliary relay is used to synchronize units between successive operations.

INSTALLATIONS

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 out-of-step switch and other cam operated switches. See the "Adjustment" section of this instruction leaflet for adjustment instructions. 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 changers. The auxiliary relays are open type construction and are intended for back-of-the-board 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

Fig. 1 shows a schematic diagram of the connections for parallel operation of three tap changers by out-of-step switch control. It will become evident as the discussion continues that, while three units are illustrated, the circuit will work equally well for two units or for more than three units by simply subtracting or adding identical units.

In Fig. 1, the paralleling switch (contacts PS1 through PS8) is shown with unit 1 set to be the master unit and units 2 and 3 to be follower units. The cam operated switches, OS1, OS2, LRA, LLA, 122, 120, are shown for a typical position of the tap changer. (For the next position, OS2 would be closed instead of OS1. For maximum lower position only, LLA would be open. For the maximum raise position only, LRA would be open). All relays are shown de-energized. The box marked "initiating circuits" represents all equipment, manual and automatic, for controlling the tap changer operation; that is, manual control switch, voltage regulating relay, line drop compensator, time delay relays. The relays shown as "SL" and "SR" represent the motor control relays or contactors which complete the circuits to the motor to cause tap changer operation. Details of the initiating and motor control circuits are given in other instruction leaflets. Fig. 1 shows a type 1 out-of-step switch.

Referring to Fig. 1, the sequence of operations of the controls is as follows:

1. a. The initiating circuits of unit 1 call for a tap change.

b. Units 2 and 3 initiating circuits are de-energized since PS1 on those units is open.

c. Assume required voltage change is in the raise direction, that is, AR closes on unit 1.

2. a. The following paths are in parallel:

1. Point A through BR, LRA, 122, PS5 of unit 1 to point B.

2. Point A through PS2 of units 1 & 2, BR, LRA, 122 and PS5 of unit 2 to point B.

3. Point A through PS2 of unit 1 and PS2, BR, LRA, 122 and PS5 of unit 3 to point B.

b. The circuit is complete from the unit 1 power supply through PS1 and AR of unit 1 to point A, through the parallel circuits to B, through OS1 of all units, through SYR of all units, to the ground bus.

c. Therefore, relays BR of all units are energized.

3. a. In unit 1, BR1 contacts seal around AR so that the following sequence will not be interrupted by contacts AR opening.

b. In each unit, individually

1. Contacts BR3 close, by-passing contacts SYR, so that the opening of SYR will not interrupt the circuit from point B to ground.

2. Contacts BR2 close, energizing SR which starts the tap changer operating.

4. a. In each unit individually contacts SR5 open.

b. Contacts SR1 close, energizing relay SYR.

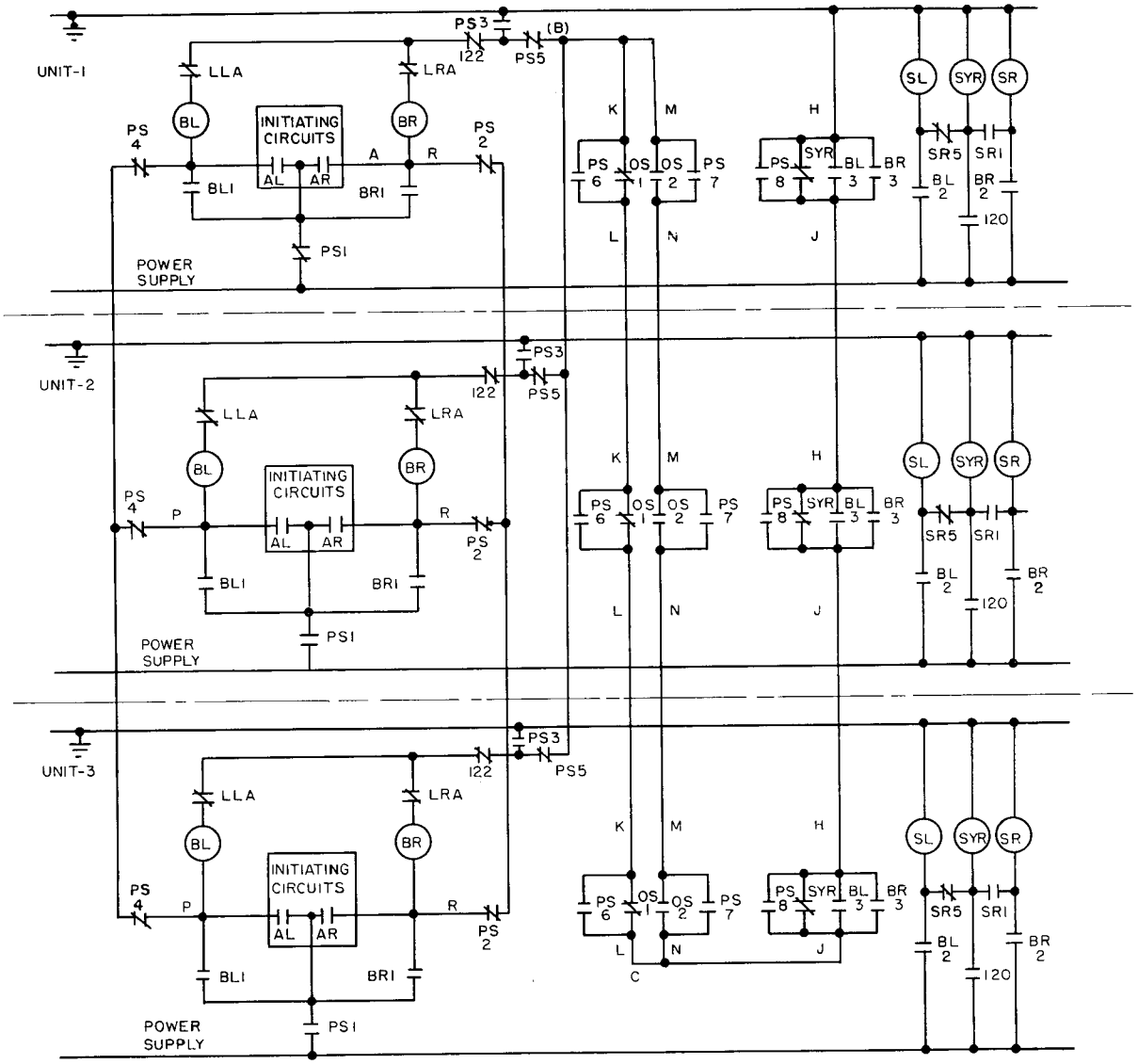
5. In each unit, individually: Contacts SYR open (but are by-passed by BR3).

6. In each unit, individually, the operation of the tap changer closes 120, by-passing BR2.

7. In each unit, individually, further operation of the tap changer opens 122, de-energizing BR.

a. BR2 opens, but is by-passed by 120.

b. BR3 opens, this opens the circuit from point B to ground.



PS SWITCH

CONTACT	INDEP.	PARALLEL FOLLOWER	PARALLEL MASTER
PS-1	X		X
PS-2		X	X
PS-3	X		
PS-4		X	X
PS-5		X	X
PS-6	X		
PS-7	X		
PS-8	X		

X=CONTACT CLOSED

FIG. 1. Schematic Diagram of Out-of Step Switch Control.

ommended, but excessive oiling should be avoided to prevent collecting dirt and grit.

During maintenance operations, the unit being worked on must be removed from service. For the case of three units in parallel, set the unit to be removed for independent operation and leave the remaining two units in parallel.

For the case of two units in parallel set both units for independent and the unit remaining in service can run automatically or manually.

For the case where a unit must be removed from the site for prolonged maintenance, the unit may be removed from the bank by connecting points K to L, M to N, and H to J and opening leads P and R as shown in Figure 1. These connections are shown on the wiring diagram furnished with the tap changer.

RENEWAL PARTS

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

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c. BR1 opens, removing the unit 1 seal around AR.

Note: Since the BR3 contacts are in series, 122 opening on any one unit, by de-energizing its particular BR relay, opens the circuit from point B to ground, de-energizing all the BR relays. It is, then, an important requirement for out-of-step switch control that the paralleled tap changers operate sufficiently alike that 120 of all units close, by-passing their respective BR2 contacts, before 122 of any unit opens

8. In each unit, individually, continued operation of the tap changer opens OS1. (This circuit has already been opened by 122 operation).

9. In each unit, individually, continued tap changer operation closes OS2. (But the circuit is still open from the operation of switch 122).

10. In each unit, individually, continued operation closes 122. The circuit is still open at SYR and BR3 contacts.

11. In each unit, individually, as the next position is reached, switch 120 opens.

a. This de-energizes both SR and SYR.

b. De-energizing SR operates the motor control equipment to stop the tap changer on position.

c. De-energizing SYR closes contacts SYR.

12. When all tap changers have reached the next position, contacts SYR of all units are closed, and the circuit is re-established from point A to ground through the previously described parallel circuits from A to B, then through the OS2 switches and the SYR switches. The initiating circuits can now start another tap change wherenever required.

In case of operation in the lower direction, the action is the same as described above except:

1. AL, BL, LLA, and SL replace AR, BR, LRA, and SR respectively throughout the description.

2. For sequence step number 3b-2, substitute: Contacts BL2 close, energizing SL and SYR. SL starts the tap changer operating. Contacts SYR open, but are by-passed by BL3.

3. Omit sequences 4 and 5.

The limit switches LLA and LRA open on the end positions, LLA at maximum lower, LRA at maximum raise, to prevent attempted operation beyond the range of the tap changers.

In case of operation starting from a position, on which OS2 is closed the operation is exactly as described above, except substitute OS2 for OS1 and substitute OS1 for OS2 wherever they appear in the sequence.

In case a Type 2 out-of-step switch is used, the circuits and operation are exactly as described above, except that the circuit from point B to point C consists of four OS series circuits instead of two.

The lock-out safety feature of out-of-step switch control results from the sequence of operations of the out-of-step switches.' The units will get out of step if one unit operates and the others fail to operate or if one unit fails to operate when the others do operate. Either case will result in one or more contacts being open in each of the series circuits between points B and C. With all circuits between B and C open, none of the BR or BL relays can be energized and therefore none of the tap changers can be operated. Thus, if the tap changers get one step apart, no further operations can be made, and therefore the maximum circulating current is limited to that caused by one step difference in the tap changer positions.

To restore operation when lock-out occurs, turn the paralleling switch of the out of step unit to the "Independent" position. This closes PS6 and PS7, by-passing the out of step switches, and closes PS8, by-passing the SYR contacts, closes PS1, and PS3 energizing the initiating circuit, opens PS2, PS4 and PS5 isolating BR and BL of this unit from the other units. The out of step unit can then be operated from its manual control switch to place it back in step. Returning the paralleling switch to parallel position then restores parallel operation. This use of the "Independent" position on all units also allows initially getting the units in step to start parallel operation.

If it is desired to by-pass one unit for independent or stand by operation and leave the remaining units operating in parallel, the following description applies.

Assume unit 1 will be the master, unit 3 will be the parallel follower, and unit 2 will be independent.

1. Turn unit 1 paralleling switch to "Parallel Master" position. This closes PS1 energizing the initiating circuits, closes PS2 and PS4 connecting BR and BL of unit 1 to the interunit busses and closes PS5 completing the circuit-through the OS switches to the control. Contacts PS3, PS6, PS7 and PS8 remain open.

2. Turn unit 3 paralleling switch to "Parallel Follower" position. This closes PS2 and PS4 and PS5 completing the BR and BL connection between units 1 and 3. Contacts PS1, PS3, PS6, PS7 and PS8 remain open.

3. Turn unit 2 paralleling switch to "Independent" position. This closes PS1 and PS3 energizing the initiating circuits, opens PS2 and PS4 isolating BR and BL from the other units, opens PS5 isolating

the control from the OS circuit, closes PS6 and PS7 by-passing the OS switches, and closes PS8 by-passing the SYR contact.

This sets up the control so that unit 3 will follow unit 1 and unit 2 will run independently. By placing any unit in any of the positions any two units can be operated in parallel with the remaining unit operating independently.

Note: For independent operation, all paralleling switches are set on "Independent". For parallel operation, the paralleling switch of all follower units is set on "Parallel Follower", but the master unit paralleling switch is set to "Parallel Master".

The actions required by the operator may be summarized as follows:

1. To operate units separately: Set all paralleling switches on "Independent". Each tap changer will operate only from its own automatic and manual control.

2. To operate all units in parallel:

a. Operate each unit separately until all units are on the same position.

b. Select the unit which is to be "Master" and move its paralleling switch to the "Parallel Master" position.

c. On all other units, set the paralleling switch on "parallel follower".

All tap changers will operate together from the automatic and manual control of the master unit.

3. To operate some units in parallel with the other units running independently:

a. Select the master unit and set its paralleling switch on "Parallel Master" position.

b. Select the follower units and set their paralleling switches on "Parallel Follower" positions.

c. Set paralleling switches of remaining units on "Independent" position.

The Master and Follower unit tap changers will operate together from the automatic and manual control of the master unit. The remaining units will operate independently form their own automatic and manual control.

ADJUSTMENT, MAINTENANCE, AND INSPECTION

When out-of-step switch control is installed at the factory, all initial adjustments are made before shipment. The following cam sequence adjustments are required only if the paralleling equipment is installed in the field.

In all cam adjustments, the 120 cam is taken as the basic gauge for the other adjustments, since the 120 cam is factory adjusted to make the tap changer stop centrally on position.

Adjustment of 122 Cam. Starting with the tap changer centrally located on position, the motion to open the 122 switch should be at least twice the motion to close 120 switch, but not more than 40% of the total motion from one position to the next.

Adjustment of OS Cam. Starting from position, the OS switch should remain closed until after 122 opens, but less than ½ the distance to the next position.

Adjustment of LRA Cam. As the tap changer approaches the maximum raise position from the next lower position, the LRA switch should open after 122 opens and before 120 opens.

Adjustment of LLA Cam. As the tap changer approaches the maximum lower position from the next higher position, the LLA switch should open after 122 opens and before 120 opens.

All cams are purposely made oversize to permit filing the edges of the cams to make the above adjustments.

The BR and BL relays should be adjusted by bending the stationary contacts of the two outer poles and by the adjusting screw on the moving contact of the center pole so that the sealing contacts, 3, by-passing SYR, close just slightly ahead of contacts, 2, operating the motor control circuits. This adjustment is especially important on BL.

In addition to the above adjustments of the paralleling equipment, the entire tap changer control should be carefully checked and adjusted, according to the instructions furnished with the tap changer. It is especially important that the brake be properly adjusted to center the tap changer on position and that the motor control relays or starters be free of any sticking or sluggishness.

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 relays, paralleling switch, and cam operated switch contacts. (The cam operated switch contacts on UR tap changers should be inspected each time the tap changer house is opened for inspection of the main contacts. On all other tap changers, the cam operated switches are accessible through hinged doors and can be inspected whenever convenient). An occasional drop of light machine oil on the roller shaft of each cam follower is rec-