DESCRIPTION • INSTALLATION • OPERATION

INSTRUCTIONS

PARALLEL OPERATION OF NON-SEQUENTIAL TAP-CHANGING-UNDER-LOAD BY OUT-OF-STEP SWITCH CONTROL

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 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 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		1	2	3	4	5	6	. . .
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.

A 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, the out-of-step switch design details depend upon the tap changer. On UR and URS tap changers, the out-of-step switch is constructed of cam operated control switches. On UNR and UT 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, either Minatrol, 16-D-3800, group 2, or Type W, 12-D-9541, group 3.

Two auxiliary relays, Type SG, Style No. 1542 926 or Style No. 1008 539.

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

The paralleling switch permits selecting the master unit or operating all units independently of each other.

The auxiliary relays, Style No. 1008 539 or Style No. 1542 926, provide the intermediate relaying stage required between the initiating and the operating circuits to permit connecting the out-of-step switch 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 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 adding or subtracting identical units.

In Fig. 1, the paralleling switch (contacts PS2, PS3, PS4, PS5), 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 an odd numbered position of the tap changer. (For an even numbered position, OS2 would be closed instead of OS1. For position 1, only, LLA would be open. For the maximum boost 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 PS5 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 of unit 1 to point B.

2. Point A through PS2, BR, LRA, 122 of unit 2 to point B.

3. Point A through PS2 of unit 2 and PS2, BR, LRA, 122 of unit 3 to point B.

b. The circuit is complete from the unit 1 power supply through PS5 and AR of unit 1 to point A, through the parallel circuits to B, through OS1 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, contacts BR2 close, energizing SR which starts the tap changer operating.

4. In each unit, individually:

a. Contacts SR5 open.

b. Contacts SR1 close.

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

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

Note: The opening of BR1 on the master unit means that, if the initiating circuit has opened contact AR, relays BR on the follower units will be de-energized. Any unit may be selected as the master unit. It is, therefore, 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.

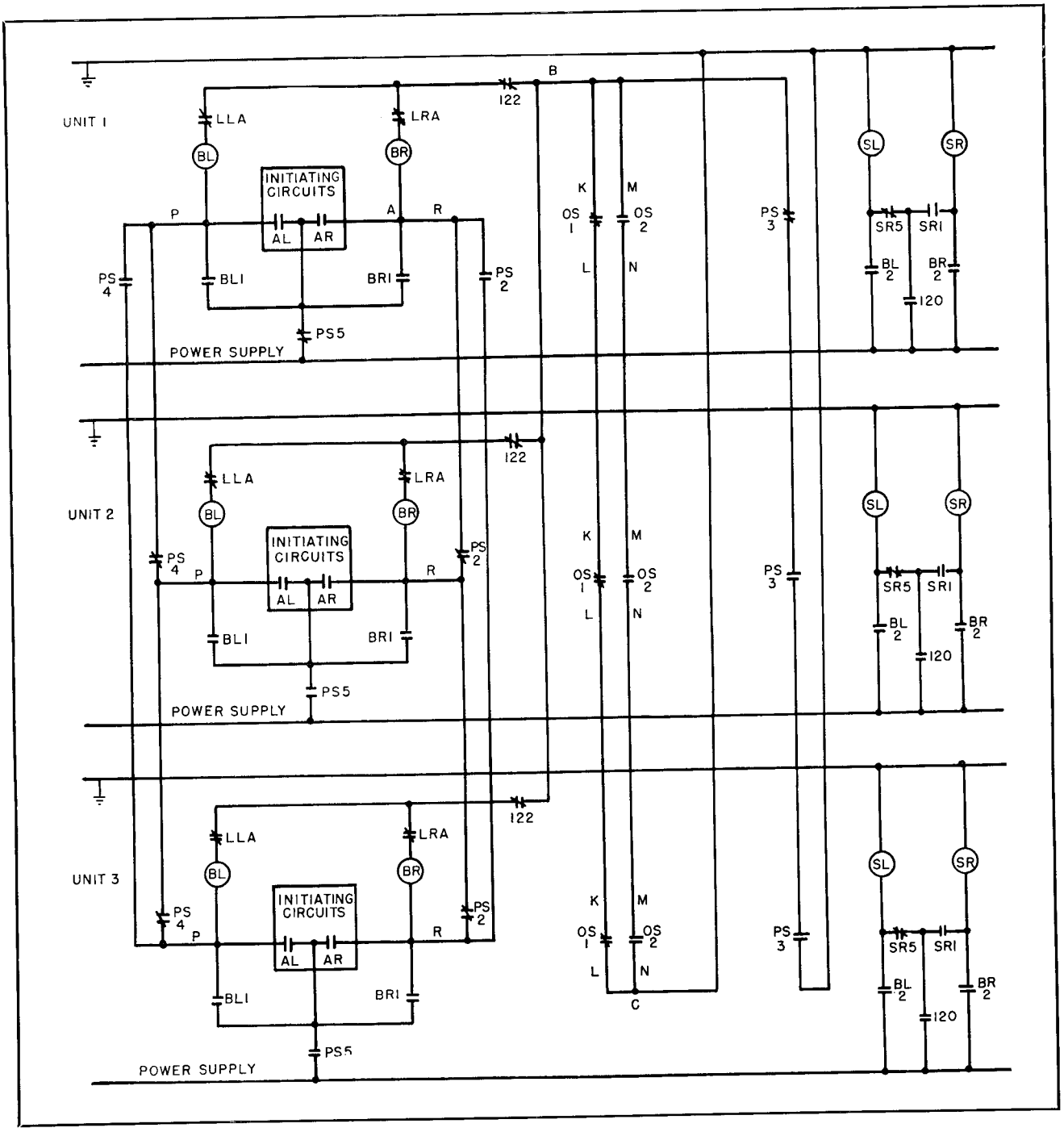

FIG. 1. Schematic Diagram of Out-of-Step Switch Control.

7. In each unit, individually, continued operation of the tap changer opens OS1. (This definitely de-energizes any BR relays not previously de-energized).

8. The non-sequential control in the initiating circuit opens AR, as described in the instruction leaflet covering that part of the control equipment.

9. In each unit, individually, continued tap changer operation closes OS2.

10. In each unit, individually, continued tap changer operation closes 122. (But AR is open).

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

a. This de-energizes SR.

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

12. When all tap changers have reached the next position, all 122 and OS2 switches are closed,

and the circuit is re-established from point A to ground through the previously described parallel circuits from A to B and through the OS2 switches. The initiating circuits can now start another tap change whenever required. Because of the non-sequential control, there will be a period of at least several seconds before the next operation.

Caution: Since the non-sequential control is on the automatic control only, special care must be exercised on manual operation to release the control switch as soon as the tap changers start operating and wait until all tap changers have completed operating before turning the control switch for another operation. Failure to observe this caution will result in energizing the controls for a second tap change at sequence step 10 instead of step 12, and will sometimes result in the units getting out-of-step.

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. Omit sequence step 4.

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

In case of operation starting from an even numbered position, 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.

Restoring Operation. To restore operation when lock-out occurs, turn all paralleling switches to the "independent" position. This closes all contacts PS3, by-passing the out-of-step switches, and opens PS2 and PS4, isolating BR and BL of each 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 switches to the "parallel" position on all except the master unit 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.

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". But the master unit paralleling switch stays on "independent".

Summary of Procedure. 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 Units in Parallel.

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

b. Select which unit will be master.

c. Do not move the paralleling switch on this master unit; leave it on "independent".

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

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

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 from position, the 122 switch should remain closed approximately 1/3 to 2/5 of the distance to the next position. It must remain closed until after 120 closes.

Adjustment of OS Cam. Starting from position, the OS switch should remain closed until after 122 opens, but not more than ½ the distance to the next position.

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

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 recommended, 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. There are two ways by which this may be done:

1. For normal maintenance, the equipment will be out of service for only a few hours. In such cases, all units should be set for "independent" and "manual" operation. Then the unit being serviced can be disconnected. An operator can control the remaining units manually to keep the regulated voltage reasonably constant by periodically operating the tap changers to balance the voltage regulating relay. The operator should always move all units one step before moving any unit a second step. (See "Note" below).

2. For prolonged maintenance, making it undesirable to keep an operator on duty, the unit being serviced may be removed from the bank by leaving the unit on "parallel", but connecting points K to L, and M to N, and opening leads P and R on Fig. 1. These connections are shown on the wiring diagram furnished with the tap changer.

Note: For the special case of two units in parallel, one can be removed from service and the other operated automatically or manually by simply setting both units for "independent" operation.

REPAIR PARTS

Order renewal parts from the nearest Westinghouse Office, or from the Sharon 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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