



DESCRIPTION • INSTALLATION • OPERATION INSTRUCTIONS

PARALLEL OPERATION BY CURRENT BALANCE CONTROL USING PARALLELING REACTOR

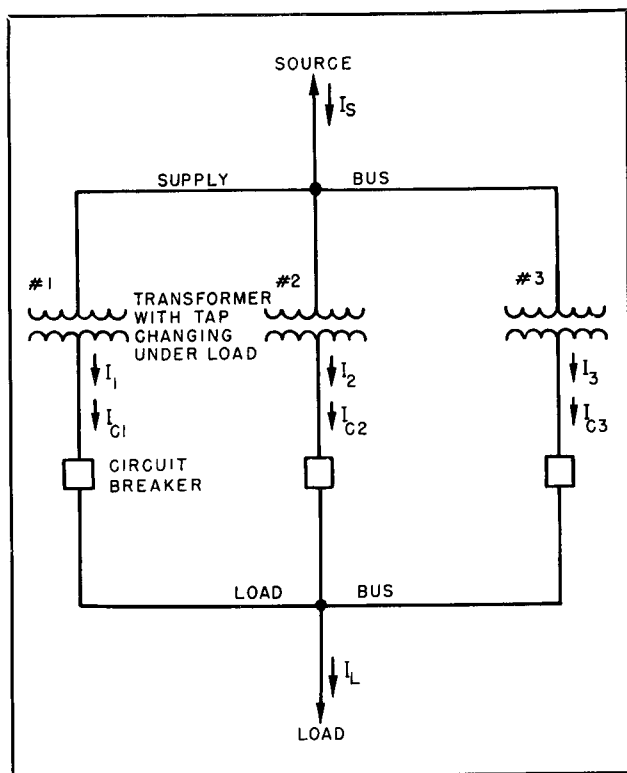


FIG. 1. Typical Circuit for Application of Current Balance Paralleling.

WHEN TWO or more tap-changing-under-load transformers are connected in parallel, any differences in voltage ratios of the paralleled units which is limited by the impedance of the loop circuit. In current balance paralleling, this circulating current is used to operate the tap changers in such a way as to reduce this circulating current to a minimum.

Sometimes when tap-changing-under-load transformers are connected in parallel, the major portion of the line drop is between the substation bus and the load center. As an optional feature in current balance paralleling, the load currents of all units can be combined so that the line drop compensation depends upon the total station load.

The paralleling requirements for the transformer, exclusive of the tap changing under load, are given in I.L. 47-600-4. This leaflet covers the equipment for parallel operation of the tap changers.

DESCRIPTION

The tap changer is operated by the standard control circuit comprising time delay and auxiliary

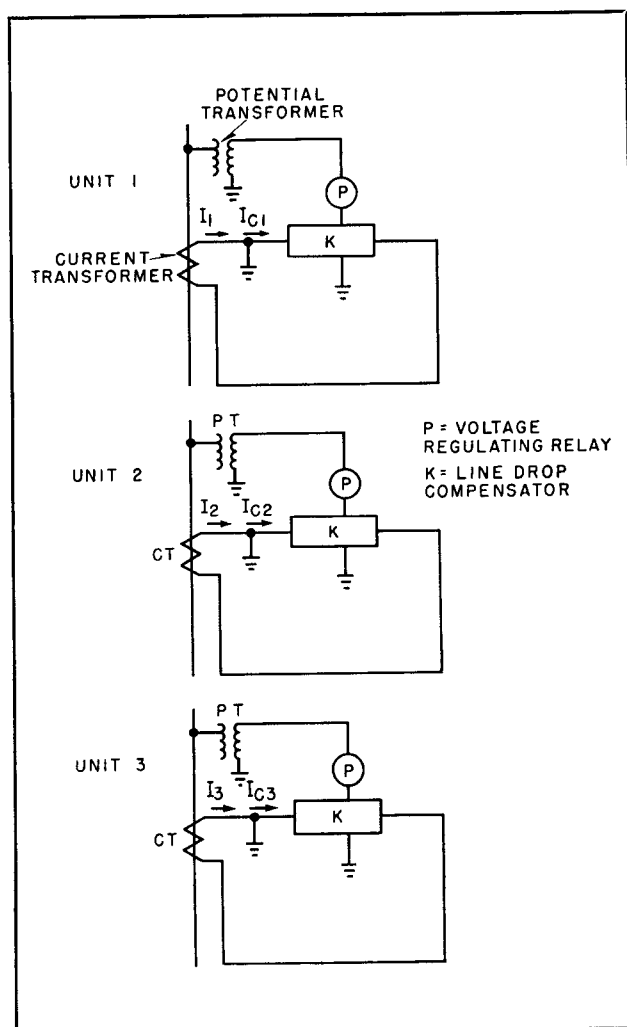


FIG. 2. Control Circuits Without Paralleling Equipment.



For current balance paralleling, the following equipment is added on each unit:

One paralleling current transformer, Style No. 1435 858.

One paralleling switch, either Minatrol 25-D-4925 or Type W 25-D-4924.

The auxiliary current transformers are interconnected between units. One network separates the circulating current from the load current. The other, optional, network equalizes the load current among all units.

The load current flows through the auxiliary current transformer, K2 in Figs. 3 and 4, and through the line drop compensators so that each compensator responds to its proportionate share of the load current. This permits adjusting the compensators according to the individual loads and lines. However, if the settings are different on different units, some circulating current may result.

The paralleling switch is a two position manually operated control switch which disconnects and bypasses the paralleling circuits to permit removing a unit from service.

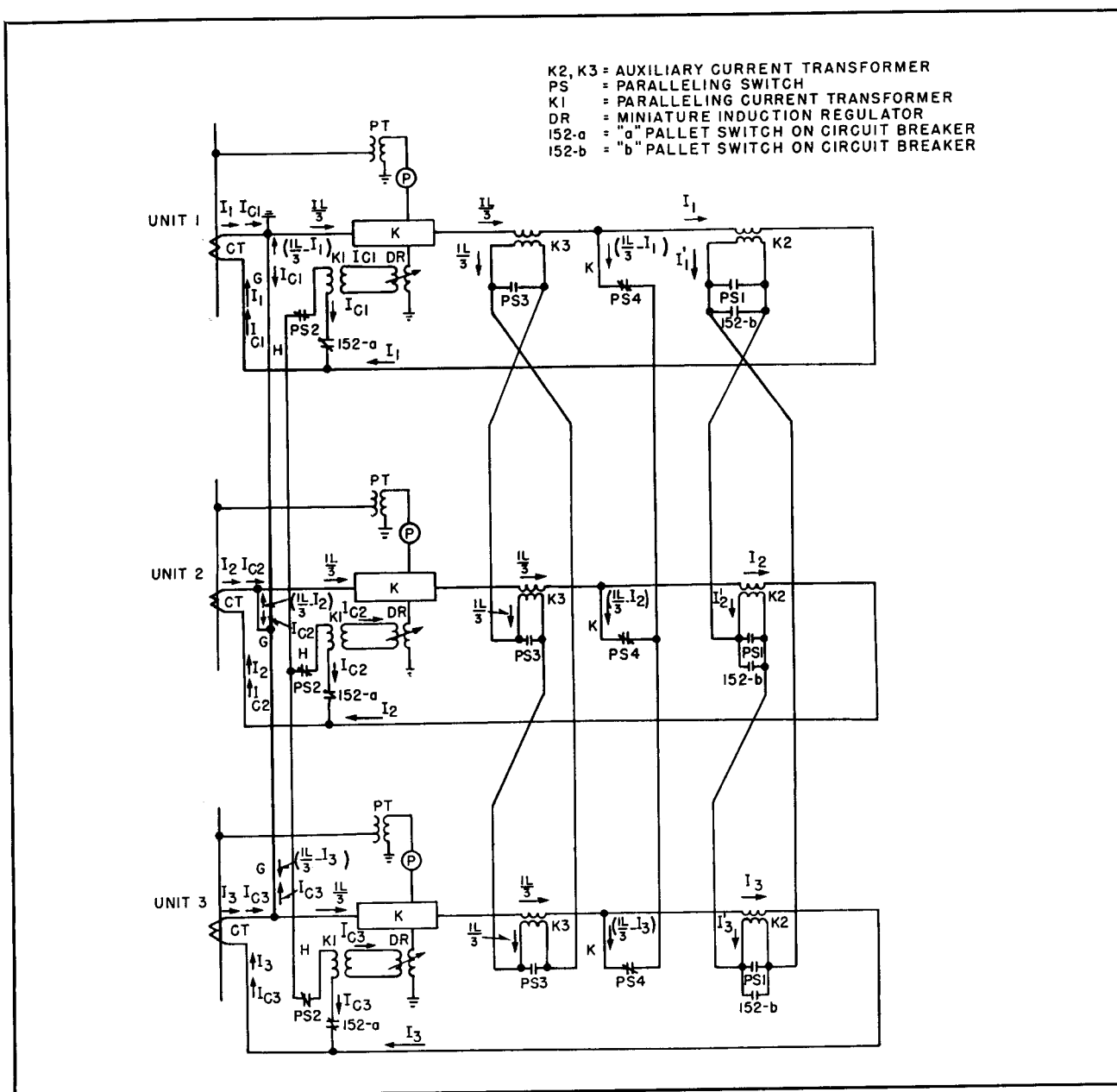


FIG. 4. Control Circuits for Current Balance Paralleling with Total Load Line Drop Compensation.

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 and drilling plans are supplied. The paralleling switch and miniature induction regulator should be mounted on a switchboard conveniently located with respect to the other control equipment for the tap changers. The current transformers may be mounted on the switchboard, or in a cubicle or accessory panel, wherever convenient for mounting and wiring. All should be located in an area

free from dirt, moisture, excessive vibration and heat.

OPERATION

The operation of the current balance system of paralleling control can best be understood by reference to the schematic sketches. Three units are illustrated, but all units are identical and any number, two or more, may be used in a similar manner.

Fig. 1 shows a typical circuit on which current balance paralleling might be applied.

Fig. 2 shows the standard, or conventional,

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3. For proper operation the K2 current transformer ratios must be selected to give equal secondary currents at normal load division between units. At the same time, the current transformer ratios for the circulating current must all be the same, since the circulating current summation must equal zero.

4. To keep all units together without hunting, all voltage regulating relays and line drop compensators must have the same settings.

ADJUSTMENT, MAINTENANCE, AND INSPECTION

The only adjustments are the tap connections on the paralleling current transformers and the setting of the miniature induction regulator. Both of these adjustments are best made by trial, and both determine the sensitivity to circulating currents. For increased sensitivity, the paralleling current transformer taps should be set for higher secondary current. The miniature induction regulator gives stepless adjustment between the current transformer taps.

The sensitivity which can be used depends upon

the loop circuit impedance, the fineness of the tap changer steps, and the number of units being paralleled. Minor differences in the paralleled circuits make it probable that the circulating current will not reduce completely to zero. The sensitivity must be reduced sufficiently that this minimum circulating current will not cause hunting. On the other hand, increased sensitivity will cause smaller circulating currents to operate the tap changers and thus keep transformer heating to a minimum. A practical operating point will usually keep the tap changers within one or two steps of each other.

The only maintenance required by the current balance paralleling equipment is occasionally blowing out any accumulated dust and dirt and inspecting the contacts of the paralleling switch.

RENEWAL PARTS

Order renewal parts from the nearest Westinghouse Office or from the Sharon, Pa. Works, giving style or S.O. number and serial number stamped on the transformer nameplate and also the style number and complete description of the part wanted.



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voltage regulating relay and line drop compensator circuits for the three transformers of Fig. 1.

Fig. 3 shows the relays and compensators of Fig. 2 with the circulating current segregation network added for current balance paralleling.

Fig. 4 shows the circuits of Fig. 3 with the addition of the optional load balance network.

In these figures, the currents are indicated by arrows identified as follows:

I_1, I_2, I_3 = load current in transformer units 1, 2, and 3 respectively as determined by the circuit constants

I_{c1}, I_{c2}, I_{c3} = circulating current in transformer units 1, 2, and 3 respectively as caused by any voltage ratio unbalance

$I_L = I_1 + I_2 + I_3$ = total load of the bank

$I_{c1} + I_{c2} + I_{c3} = 0$, since no circulating current appears beyond the source and load buses

In Fig. 1, the current in each unit is shown in terms of the main power circuit. The total current in each unit is the vector summation of the load and circulating currents, or $I_{unit 1} = I_1 + I_{c1}$, $I_{unit 2} = I_2 + I_{c2}$, $I_{unit 3} = I_3 + I_{c3}$.

In Fig. 2, the same currents are transferred to the conventional control circuits. If it were attempted to operate with just this control, the operation would be unstable. For example, assume that unit 1 has a slightly shorter time delay relay setting than units 2 and 3, so that it operates first to raise its voltage. Then, unit 1 having higher voltage output, the circulating current is positive in unit 1 and negative in units 2 and 3. Therefore, the moment unit 1 operates, the currents become: $I_{unit 1} = I_1 + I_{c1}$, $I_{unit 2} = I_2 + (-I_{c2})$, $I_{unit 3} = I_3 + (-I_{c3})$. Increased current in unit 1 causes its line drop compensator to operate the voltage regulating relay to cause additional "raise" operations of the tap changer. Decreased current in units 2 and 3 cause their line drop compensators to operate the voltage regulating relays to cause "lower" operations of the tap changers. Thus, with only the

conventional control, the first unbalance which creeps into the system becomes cumulative until the tap changers reach their limit positions.

Fig. 3 shows the circuits which are added in current balance paralleling to cancel, and in fact reverse, this cumulative tendency. In each unit, the current in the main current transformer is the same as before, $I_{unit 1} = I_1 + I_{c1}$, $I_{unit 2} = I_2 + I_{c2}$, $I_{unit 3} = I_3 + I_{c3}$. An auxiliary current transformer, K2, has its primary connected in series with each line drop compensator, and its secondary connected in series with the secondaries of all the other K2 transformers. The K2 ratios are selected so that the normal values of I_1, I_2 , and I_3 , as determined by the circuit capacities and impedances, make $I_{1s} = I_{2s} = I_{3s}$. (For example, if all units are the same Kva rating, K2 has the same ratio on all units. If unit 1 is twice the Kva rating of units 2 and 3, K2 will make the overall ratio of CT plus K2 in unit 1 twice the corresponding ratio for units 2 and 3). Since $I_{1s} = I_{2s} = I_{3s}$, the series circuit of the K2 secondaries is a very low impedance circuit to I_1, I_2 , and I_3 and allows I_1, I_2 , and I_3 to flow through the line drop compensators, K.

However, I_{c1}, I_{c2} , and I_{c3} cannot be similarly balanced since $I_{c1} + I_{c2} + I_{c3} = 0$. Therefore, the series connection of K2 secondaries presents a high impedance to the circulating current, forcing it to flow into the common connection, G and keeping it out of the line drop compensator. At G, $I_{c1} + I_{c2} + I_{c3} = 0$, which means that a positive I_{c1} , at this point, becomes a negative component of I_{c2} and/or I_{c3} and, as such, flows through the current transformers and K1, PS2 and 152a, of units 2 and/or 3 in the negative direction to H. At H, it recombines and again becomes positive I_{c1} , flowing through 152a, PS2, and K1 of unit 1 back to the unit 1 current transformer. (Note: If all units do not have the same CT ratio, auxiliary transformers must be used in leads G and H in order that the overall ratio will be the same to make I_{c1}, I_{c2} , and $I_{c3} = 0$ at G and H).

The currents I_{c1}, I_{c2} , and I_{c3} flow from the secondaries of K1 to the miniature induction regulators, DR, producing voltages in the voltage regulating relay circuit. DR is designed to be

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reactive, since, in Fig. 1, the loop impedance to the circulating current is largely reactive. The polarity of DR is reversed, relative to the line drop compensator, so that increased positive circulating current causes the voltage regulating relay to operate the tap changer in the "lower" direction. Operation in the "lower" direction reduces the positive circulating current. Thus, the paralleling circuits operate the tap changers toward minimum circulating current, and this control is in addition to and independent of the line drop compensation due to K and I_1 , I_2 , and I_3 .

The circuit breaker pallet switches, 152-a and 152-b, are shown in Fig. 3 with the circuit breakers all closed. Suppose that the circuit breaker of unit 3 opens; then contacts 152-b close and contacts 152-a open. The closing of 152-b provides a by-pass around K2 of unit 3 for the series circuit so that $I_{1S} = I_{2S}$ satisfies the equality requirements of K2 and permits I_1 and I_2 to flow through their respective line drop compensators even though I_3 is now zero. The opening of 152-a opens the circuit through K1 to prevent any portion of the circulating current taking the path from G through K, K2, and K1 of unit 3 to H. Thus, when the circuit breaker of unit 3 opens, units 1 and 2 continue to operate in parallel as a bank of two units.

The paralleling switch contacts PS1 are in parallel with 152-b and contacts PS2 are in series with 152-a, so that the paralleling switch provides a means of manually removing a unit from parallel operation. With K2 by-passed by PS1 and with the circulating current path opened by PS2, the control of that unit is effectively the same as Fig. 2. Thus, if by bus switching, unit 3, for example, is connected to a different load than units 1 and 2, the paralleling switch of unit 3 can be set on "independent" and unit 3 will operate and regulate its load without either affecting the parallel operation of units 1 and 2 or being affected by units 1 and 2.

In Fig. 4, the K3 network is added for making the line drop compensators respond to total load current instead of to the currents in the respective units. The K3 network is exactly the same as the K2 network except that contacts 152-b are omitted, the K3 current transformers are all the same ratio

regardless of the unit Kva's, and the interconnection through PS4 is a direct connection with no elements corresponding to K1. Currents I_1 , I_2 , and I_3 flow through K2 as described for Fig. 3. However, because K3 ratios are all the same, equal currents must flow through the line drop compensators and K3 primaries; this current is $I_L/3$ (or $I_L/2$ for two units, $I_L/4$ for four units, etc.). Any difference between I_1 , for example, and $I_L/3$ flows through connection G to unit 2 or 3 where it adds to I_2 or I_3 to make $I_L/3$ through K of those units. This is possible since $I_1 + I_2 + I_3 = I_L$ and $3 \times I_L/3 = I_L$. Leaving K3, the corresponding currents flow through PS4 so that I_1 , I_2 , and I_3 flow through K2, as in Fig. 3. Since the current in each compensator is $I_L/3$ and since there are no 152-b contacts, each unit will have its share of the total load current regardless of how the load divides between units or how many circuit breakers open.

The paralleling switch contacts PS3 by-pass K3 as PS1 by-passes K2 and PS4 opens K as PS2 opens H, so that setting the paralleling switch of one unit on "independent" removes that unit from the bank, permits it to operate independently and lets the remaining units operate as a bank of two units.

Limitations. The operation of current balance paralleling circuits will automatically respond to changing load conditions and will operate to keep circulating current to a minimum. However, there are a few limitations which should be noted and recognized.

1. The circulating current response is through the standard control which included time delay relays. During this time delay the circulating current is limited by the loop impedance only.

2. In case any part of the tap changer or its control should fail to operate correctly, it is possible for the tap changers to become separated by the full tap range. Unless the loop impedance is sufficiently large, the resultant circulating currents may cause dangerous overloading of one or more of the transformers. Where such a possibility exists, suitable overload alarm device should be provided.