INSTRUCTIONS

PARALLEL OPERATION

OF TCUL* TRANSFORMERS IN DOUBLE-ENDED UNIT SUBSTATIONS USING "SU" RELAY AND LINE-DROP COMPENSATOR

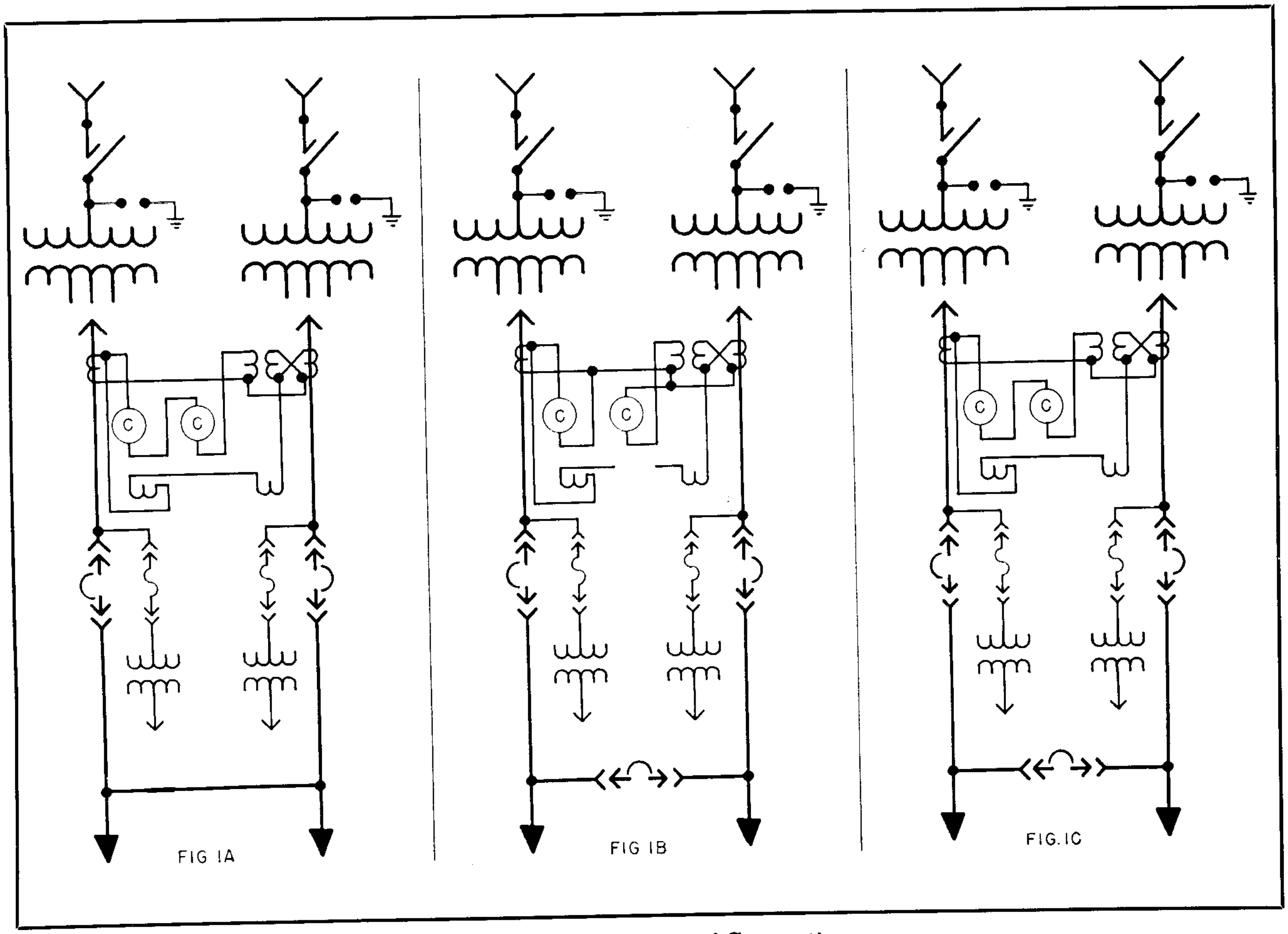

FIG. 1. Block Diagram of Connections.

CONDITIONS OF OPERATION

Fig. 1 shows the three conditions for parallel operation in double-ended unit substations.

Fig. 1A shows two transformers operating in parallel, feeding a common low-voltage bus which is regulated by both transformers. Both compensators must have the same setting.

Fig. 1B shows two transformers normally operating independently with the low-voltage tie breaker open. This breaker keeps the low-voltage buses independent of each other and each transformer regulates its own bus. Each compensator must be set to meet feeder load conditions and these settings may or may not be the same. Fig. 1C shows the operation of Fig. 1B when one transformer has been de-energized and the remaining unit is carrying the full load.

OPERATION OF CONTROL

Fig. 2 is a schematic of connections for operation as shown in Fig. 1A. This diagram shows the circuit requirements for two transformers feeding a common low-voltage bus.

*Tap Changing Under Load

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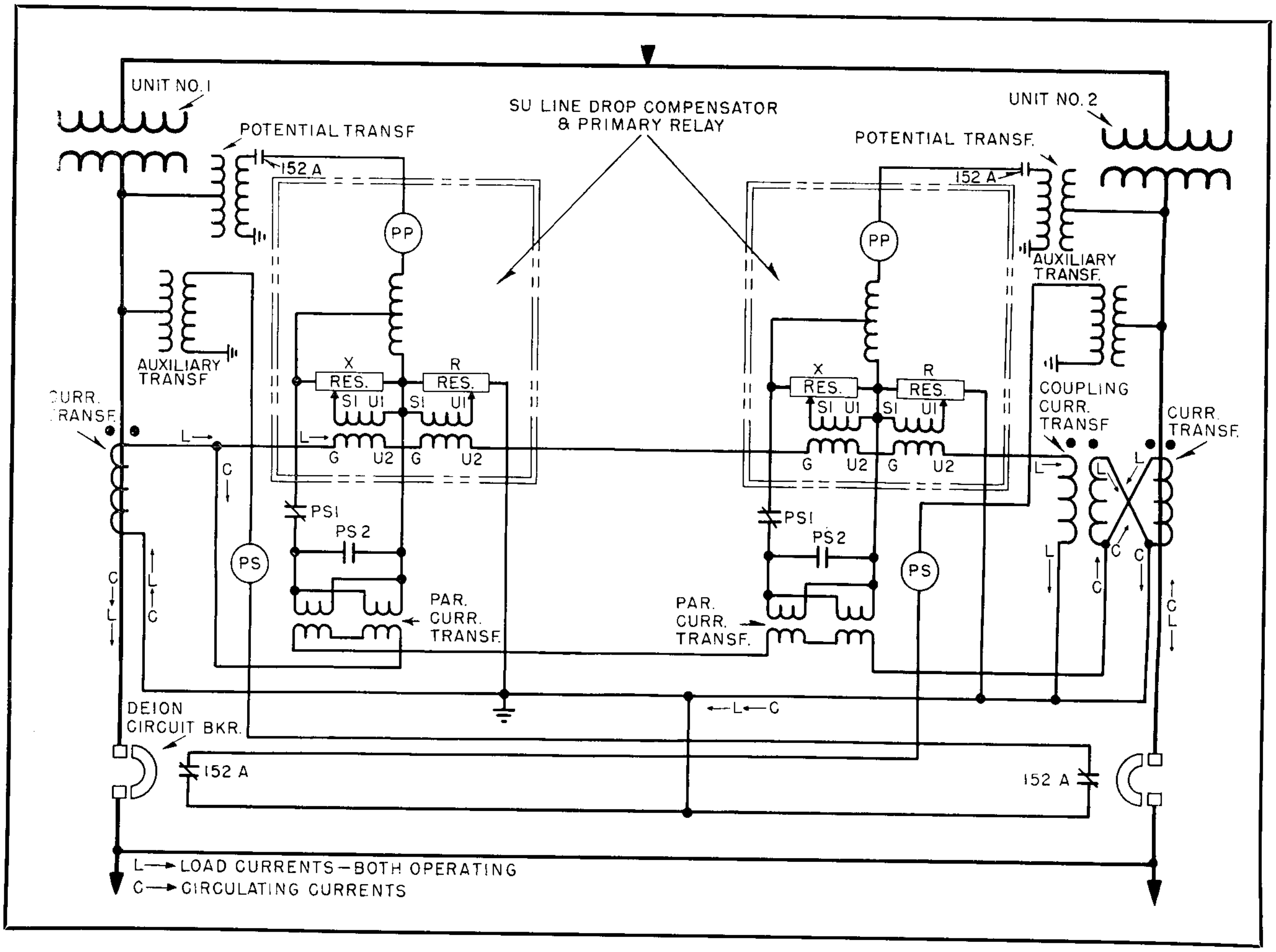

FIG. 2. Schematic Diagram of Connections—Two Units Feeding Common Bus (See Fig. 1A).

For units of equal kva rating, the coupling current transformer will be 5-5 ratio. For other ratings, the coupling current transformer ratio will be the ratio of the currents in secondaries of the current transformers at the rated loads of main units. Also, the ratio of both main current transformers must be the same.

When each transformer is carrying rated load, the currents in the secondaries of the coupling and Unit 1 current transformers are equal. This current flows from the polarity marker of Unit 1 current transformer through the line-drop compensators, the secondary of the coupling current transformer, and back to Unit 1 current transformer through the grounded lead. There is no current through the paralleling current transformer as the secondary current of Unit 2 current transformer is coupled to Unit 1 current transformer through the coupling current transformer, thereby meeting secondary current and circuit requirements.

If the tap changers are out of step, a current circulates around the power loop formed by the two transformers in parallel and is limited by the difference in voltage and the impedances of the transformers.

For example, assume sufficient current circulating in the power loop to produce 5 amperes out of the polarity marker of Unit 1 current transformer. This will produce 5 amperes in at the polarity marker of Unit 2 current transformer if the current transformer ratios are equal.

These currents cannot be coupled by the coupling current transformer as they are of opposite polarity. Therefore, the 5 amperes are forced through the paralleling current transformers.

The circulating current in the loop is approximately 90 degrees out of phase with the load current. The voltage generated in the "X" element of the line-drop compensator by this current is in phase with voltage on the primary relay of Unit 1, and in opposition with voltage on the primary relay of Unit 2. Thus the primary relay of

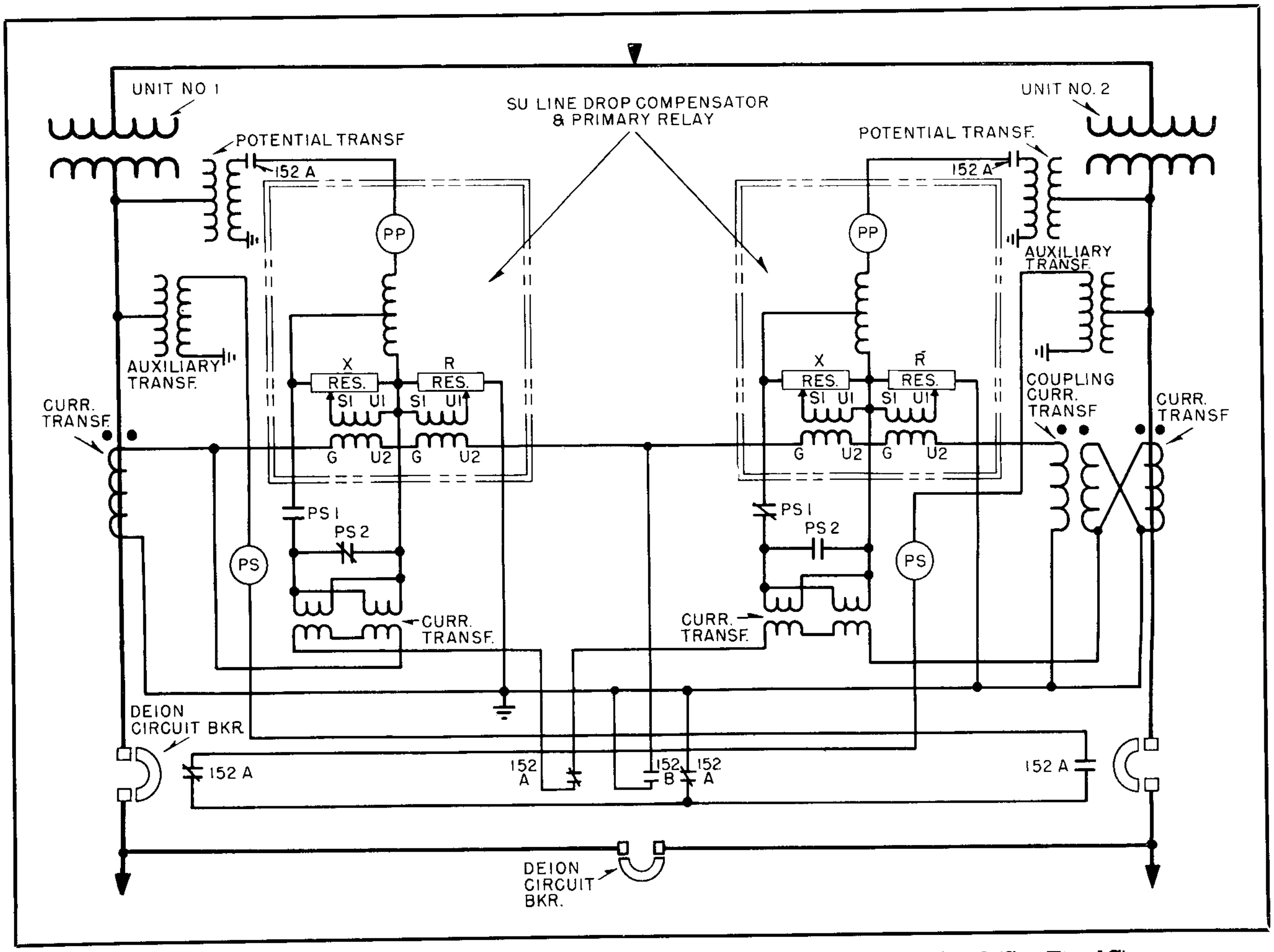

FIG. 4. Schematic Diagram of Connections—One Unit Carrying All the Load (See Fig. 1C).

ling ratio of 10-5 amperes. Then 1.66 amperes will flow through the SU compensator and 3.33 amperes through the shorted disconnected paralleling current transformers.

Using SU current transformers as paralleling transformers, approximately 5 percent circulating current would operate tap changers to reduce circulating current.

The load and circulating currents are shown on the diagram by arrows followed by the letter "L" or "C".

Fig. 3 is a schematic of connections for operation as shown in Fig. 1B. This diagram shows the circuit requirements for two transformers of equal kva normally operating independently with the low-voltage tie breaker open. This diagram is the same as Fig. 2, except for the connection of the compensators and the addition of the low-voltage tie breaker and its auxiliary contacts 152A and 152B. These contacts are connected so that with the tie breaker open, the line between the two compensators is connected to ground through the 152B contact, the paralleling current transformer primaries are opened by one of the 152A contacts, and the paralleling relays PS are controlled by the remaining 152A contact.

Since each transformer is operating independently, each low-voltage bus is regulated by its own transformer and each compensator is adjusted to meet individual load conditions. There is no circulating current and the load current of each unit is shown by arrows followed by the letter "A" or "B".

The burden of each paralleling current transformer is removed from its compensator because the 152A contact of the tie breaker is open.

If one transformer breaker were open and the remaining transformer were carrying the full load, the operation would be as described in the following paragraphs for Fig. 4.

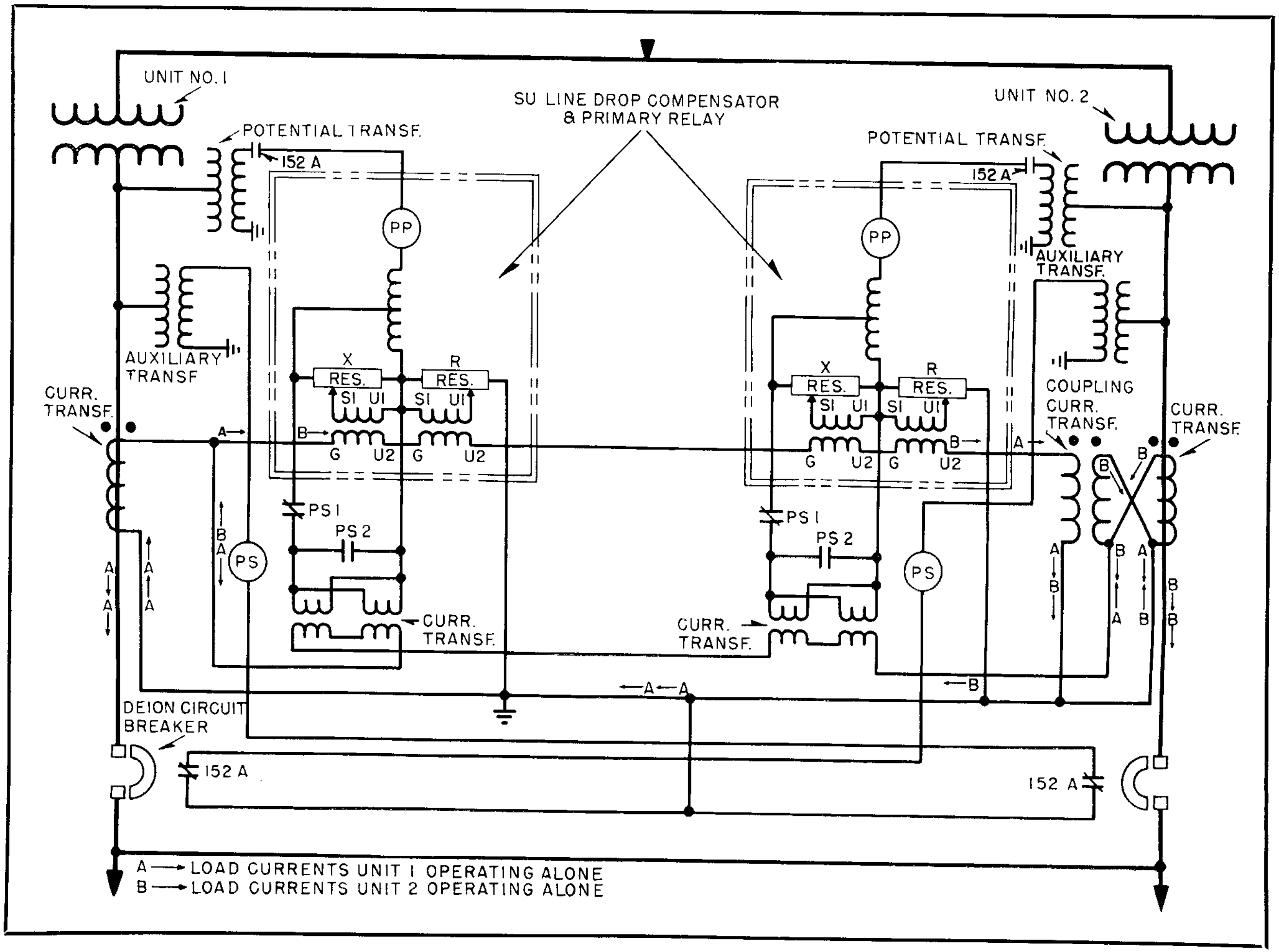

FIG. 5. Schematic Diagram of Connections—Division of Currents for One Unit Alone.

Fig. 4 is a schematic of connections for operation as shown in Fig. 1C. This diagram shows the circuit requirements for operation when one transformer is de-energized.

Assume, for example, Unit 1 to be carrying the full load with Unit 2 de-energized and the low-voltage tie breaker closed. The breaker contacts 152A and 152B are now reversed so that the line between the two compensators is removed from ground by opening the 152B contact, the primaries of the paralleling current transformers are connected by one of the 152A contacts, and the circuits to the paralleling relays PS are completed by the remaining 152A contact.

The burden of the paralleling current transformer secondary is removed from Unit 1 compensator due to the 152A contact of Unit 2 breaker being open. This de-energizes PS on Unit 1 so that contact PS1 is open and PS2 is closed, thus disconnecting and shorting the secondary.

The compensation would still remain correct as explained under the operation of Fig. 2. With conditions reversed so that Unit 2 were carrying the full load with Unit 1 de-energized, the burden of the paralleling current transformer would be removed from Unit 2 compensator by the action of the 152A contact of Unit 1 breaker and the compensation would still be correct.

The distribution of the load currents is shown in Fig. 5.

The two transformers could also be normally operated in parallel. Under this condition the circuits are effectively the same as for Fig. 2, and the compensators are set the same. If one unit becomes de-energized, the compensation would still be correct as described under the operation of Fig. 2.

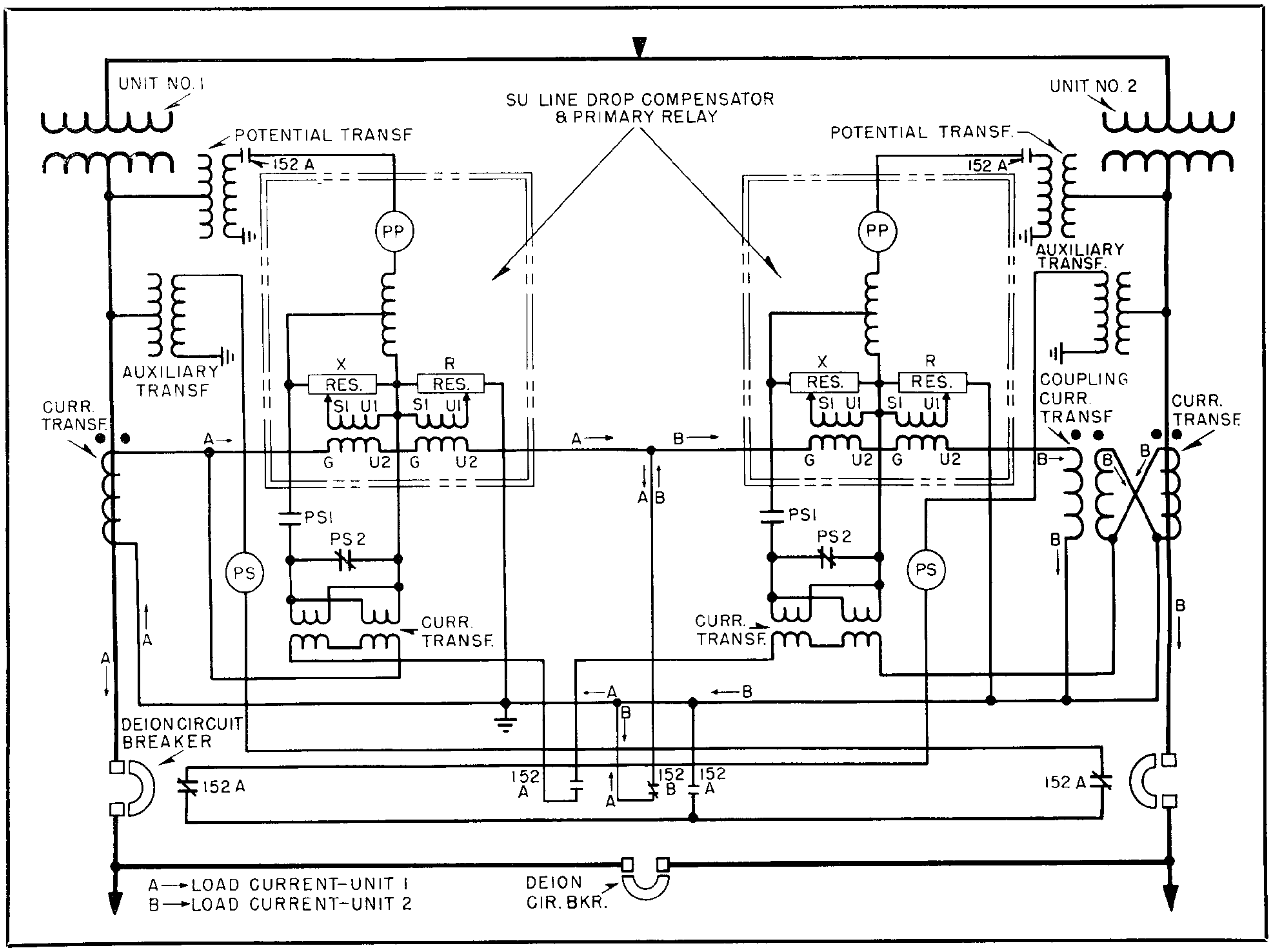

FIG. 3. Schematic Diagram of Connections—Two Units Independent (See Fig. 1B).

Unit 1 acts to lower its voltage, and primary relay of Unit 2 acts to boost its voltage until voltages are balanced and circulating current is reduced. If one tap changer should somehow fail to operate, the other will operate within its range to limit circulating current.

When the total load is within the capacity of either transformer, either transformer may be operated alone. To obtain proper compensation under this condition, the paralleling current transformer is automatically removed so that it will not counteract the line-drop reactance compensation. For example, assume Unit 1 operating alone with Unit 2 breaker open. Its auxiliary contact 152A, which is in series with paralleling relay PS on Unit 1 is open, and relay PS is de-energized. This opens PS1 and closes PS2 contacts, thus removing and shorting the paralleling current transformer of Unit 1.

The same action occurs to Unit 2 if it is operating alone. Also, if either unit is de-energized, the circuit breaker auxiliary contact 152A removes the potential from its primary relay to make it inoperative.

Assuming Unit 1 to be carrying full load current alone so that the secondary of its current transformer is carrying 5 amperes, the division of this current (caused by the 5/5 coupling transformer) will be 2½ amperes through SU line-drop compensators and 2½ amperes through the shorted disconnected paralleling current transformers. If the same load were carried by Unit 2, the current will divide 2½ amperes through SU line-drop compensator and shorted disconnected paralleling current transformers, and 2½ amperes through the coupling transformer. Thus, if the paralleling transformers are disconnected from the SU compensator, the line-drop compensation is the same for either or both transformers carrying the same total load. For unequal kva transformers, the current will divide in the ratio of the coupling current transformer. For example, assume a coup-

POTENTIAL AND AUXILIARY TRANSFORMER LOCATION

To obtain proper operation of these systems, it is necessary to take the potential and auxiliary power supplies from the transformer side of the main breakers. Both tap changers will pull into step due to the operation of the paralleling circuits and need not be lined up manually before closing in a de-energized unit.

ADVANTAGES

With proper installation this system of paralleling will give satisfactory operation, and the advantages obtained through its use are:

1. When the circuit breaker is reclosed after one unit has been removed from the line, both tap changers will pull into step automatically.

2. Bus regulation and compensation is correct regardless of whether one or both transformer units are operating.

3. Operation is entirely automatic and it is not necessary to go to the substation to change-over controls due to switching operations.

4. Minimum number of leads between units.

5. Can be applied to dissimilar tap changers and units with different percentage steps and ranges, or units already in service.

DISADVANTAGES

1. Malfunction of apparatus may cause circulating currents harmful to the transformer unless protective devices are provided, such as thermal relays.

2. Limited to relatively high impedance loops such as those containing transformers of normal impedance.

3. Limited to two units in parallel.

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