INSTRUCTIONS

PARALLEL OPERATION BY CURRENT DIFFERENCE COMPENSATION

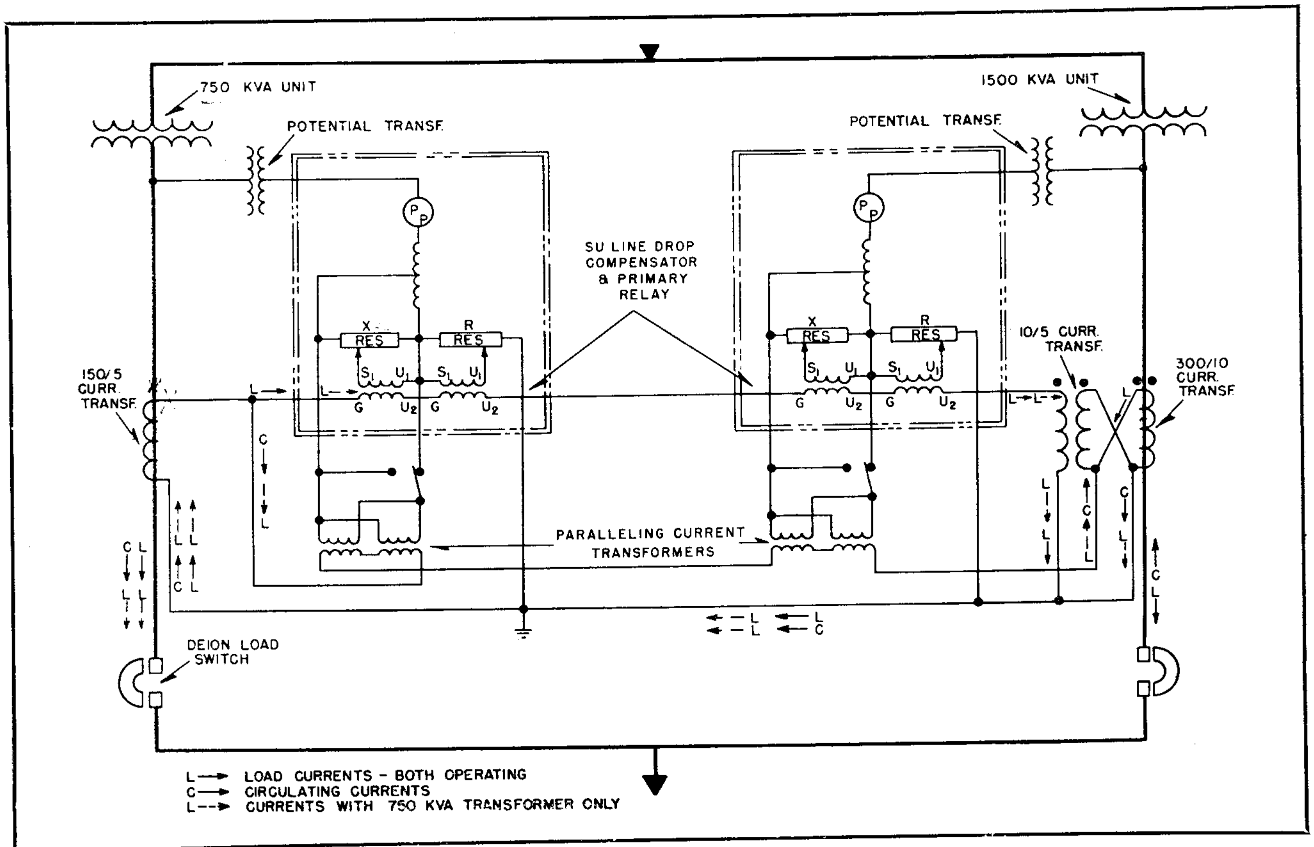

FIG. 1. Schematic Diagram of Connections

Figure 1 is a schematic diagram of connections for paralleling two transformers with Tap-Changing-Under-Load equipment. This diagram shows the requirements for two transformers of 750 and 1500 kva rating. For equal rating units the coupling current transformer would be 5-5 ratio. For other ratings the coupling current transformer ratio would be the ratio of the currents in secondaries of the current transformers at the rated loads of main units.

When each transformer is carrying load proportional to its rating, the currents in the secondaries of the 10/5 and 150/5 current transformers are equal. This current flows from the polarity marker of the 150/5 current transformer through both the line drop compensators, the secondary of the 10/5 current transformer and back to the 150/5 current transformer through the grounded lead. There is no current through the paralleling current transformers as the secondary current in the 300/10 current transformer is coupled by the 10/5 current transformer to the 150/5 current transformer secondary current and circuit requirements are met.

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.

Assume, for example, 150 amperes circulating counter-clockwise in the power loop. This will

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produce 5 amperes out of the polarity marker on the 150/5 current transformer and 5 amperes in at the polarity marker on the 300/10 current transformer. This equal ratio is necessary because the circulating currents in the units are equal, irrespective of transformer ratings. These currents cannot be coupled by 10/5 current as they are of opposite polarity. The 5 amperes are therefore forced through the paralleling current transformers.

The circulating current is reactive, since it is determined by the transformer and connecting line impedances. The voltage generated in the "X" element of the line drop compensator by this current is approximately in phase with the voltage on the primary relay of the 750 kva unit and in opposition with the voltage on the primary relay of the 1500 kva unit. Thus the primary relay of the 750 kva unit acts to lower the voltage of the 750 kva unit and the relay of the 1500 kva unit 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, that transformer may be operated alone. In this case it is desirable to disconnect the paralleling current transformer from the compensators so that their voltages will not counteract the line drop reactance compensation.

Assuming the 750 kva unit to carry full load current alone, the division of current (caused by 10/5 coupling transformer) will be 1.66 amperes through SU line drop compensators and 3.33 amperes through the shorted, disconnected, paralleling current transformers. If this same load were carried by the 1500 kva unit the current would divide 1.66 amperes through SU line drop compensators and shorted, disconnected, paralleling current transformers, and 3.33 amperes through the 10-ampere winding of 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.

If the paralleling current transformers are the same ratio as the internal current transformers used inside the SU compensator, approximately 8 percent circulating current would operate tap changers to reduce circulating current, assuming a ± 1.5 volt band-width setting on the voltage regulating relay.

This method of paralleling requires only a few wires between units and requires no additional limit or pilot switches on the tap changer mechanism. If a new unit is to parallel with an existing unit, all necessary equipment is mounted on the new unit and it is only necessary to connect a few wires between units and check polarity of the compensators to put the paralleling circuits in operation.

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The theoretically ideal conditions for paralleling transformers are:

1. Identical turns ratios and voltage ratings.
2. Equal percent impedances.
3. Equal ratios of resistance to reactance.
4. Same polarity.
5. Same phase angle shift.
6. Same phase rotation.

Single Phase Transformers. For single phase transformers only the first four conditions apply as there is no phase rotation or phase angle shift due to voltage transformation.

If the turns ratios are not the same a circulating current will flow even at no load. If the percent impedance or the ratios of resistance to reactance are different there will be no circulating current at no load, but the division of load between the transformers when applied will no longer be proportional to their KVA ratings.

Three Phase Transformers. The same conditions hold true for three phase transformers except that in this case the question of phase rotation and phase angle shift must be considered.

Phase Angle Shift. Certain transformer connections as the wye-delta or wye-zigzag produce a 30° shift between the line voltages on the primary side and those on the secondary side. Transformers with these connections therefore cannot be paralleled with other transformers not having this shift such as wye-wye, delta-delta, zigzag-delta, or zigzag-zigzag.

Phase Rotation. Phase rotation refers to the order in which the terminal voltages reach their maximum values. In paralleling, those terminals whose voltage maximums occur simultaneously are paired.

Power Transformer Practice. The preceding discussion covered the theoretically ideal requirements for paralleling. In actual practice good paralleling is obtained even though the actual transformer conditions deviate by small percentages from the theoretical ones.

Good paralleling is considered as attainable when the percentage impedances of two winding transformers are within 7.5% of each other. For multi-winding and auto-transformers the generally accepted limit is 10%.

Furthermore, in power transformers of normal design the ratio of resistance to reactance is generally sufficiently small to make the requirement of equal ratios of negligible importance in paralleling.

When it is desired to parallel transformers having widely different impedances, reactors or auto-transformers having the proper ratio should be used. If a reactor is used it is placed in series with the transformer whose impedance is lower. It should have a value sufficient to bring the total effective percent impedance of the transformer plus the reactor up to the value of the percent impedance of the second transformer. When an auto-transformer is used, the relative currents supplied by each transformer are determined by the ratio of the two sections of the auto transformer. The auto-transformer adds a voltage to the voltage drop in the transformer with the lower impedances and substracts a voltage from the voltage drop in the transformer with the higher impedance. Auto-transformers for use in paralleling power transformers are designed especially for each installation. The method of connecting the auto-transformer is shown in a wiring diagram furnished with each installation.

In general, transformers built to the same manufacturing specifications as indicated by the nameplate may be operated in parallel.

In connecting transformers in parallel when the low tension voltage is comparatively low, care should be taken to see that corresponding connecting bars or conductors have approximately the same impedance, otherwise the currents will not divide properly.

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