TECHNICAL BULLETIN

T-016

PARALLEL OPERATION OF AC ELECTRIC GENERATING PLANTS

JULY 1968

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A DIVISION OF STUDEBAKER CORPORATION

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SECTION I
DEFINITION OF TERMS

1. PARALLEL OPERATION

The operation of two or more sources of AC electrical power connected to a common load. The 2 or more sources perform as a single electric power source.

2. OPERATING SOURCE

The electric plant or commercial powerline that is delivering power to a load.

3. INCOMING PLANT

An electric plant that is being paralleled with an operating source.

4. SYNCHRONIZATION

Accomplished when 2 or more electric plants are matched in frequency, in voltage, and in phase sequence.

5. SYNCHRONIZING LIGHTS

Small lights connected across the line contactor of the incoming plant indicating when the voltage and frequency of the incoming and operating sources are or are not in synchronism.

6. PHASE SEQUENCE

The order in which the voltage of a particular phase appears at the output terminals of a three phase electric plant.

7. GOVERNOR

A device that maintains constant engine speed under various load conditions. It must have provision for adjustment of speed (which controls generator frequency) and speed droop, from no-load to full-load.

8. VOLTAGE CONTROL

A rheostat that sets the operating point of the voltage regulator and therefore controls the output voltage of the electric plant, within its design limits.

9. INTERNAL VOLTAGE

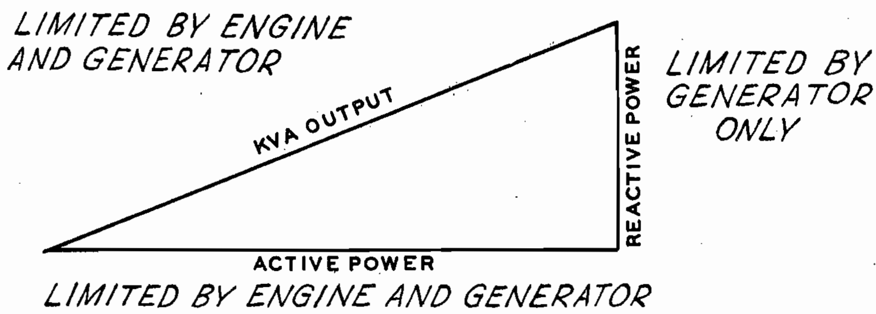
The actual voltage a generator would develop at no-load if it were not connected in parallel operation. Excitation of the generator field controls internal voltage.

10. ACTIVE POWER (KW)

Active power does the work of heating, turning motor shafts, etc. The horsepower output of the electric plant engine limits the active or real power capability of the electric plant.

11. REACTIVE POWER (KVAR)

Reactive power flows between the inductive windings of the generator and the inductive or capacitive portions of the electrical load. Reactive power does no useful work in the electrical load nor does it present load to the engine. It does limit the capacity of the generator. The diagram shows the relationship between the active power, reactive power, and KVA output of an electric plant.



12. CROSS CURRENTS

Currents that circulate between paralleled plants when the internal voltage of one plant is different from the other. The plant with the higher internal voltage supplies reactive power to the other plant. The amount of cross current is a measure of this exchange of reactive power.

13. CCT

Cross Current Transformer.

14. PST

Phase Shifting Transformer. This is used in conjunction with a CCT to produce a 90° phase shift between the line current and the secondary voltage of the PST. Used in single phase systems only.

15. CCR

Cross Current Resistor. An adjustable power resistor connected to the secondary winding of the CCT. It supplies a voltage drop in the voltage regulator circuit proportional to the line current supplied by the plant.

16. E_X

Reactive Bias Voltage. Voltage that appears across the CCR or PST. It is 90° out of phase with the line current.

17. E_D

Droop Voltage. It is the component of the voltage E_X that affects the voltage regulator signal. It is proportional to the reactive component of the line current. It is also the designed voltage droop in the output voltage when the plant is supplying its rated KVA.

18. I_{FL}

Full Load Line Current. The current that flows, per phase, at full rated load at 0.8 power factor.

19. I_1

Primary Current. The current flowing in the primary of the CCT. I_{FL} is equal to I_1 when only one lead forms the primary of the CCT. 1.73 x I_{FL} is equal to I_1 when two leads of a 3-phase electric plant are magnetically summed by passing them through the CCT in opposite directions.

20. I_2

Secondary Current. The current that flows in the secondary of the CCT due to primary current.

21. CCT RATIO

The ratio of the CCT primary current to the secondary current, with the secondary current usually standardized at 5 amperes.

22. N_1

CCT primary turns. The number of times each primary lead passes through the CCT.

23. CCT VA

Cross Current Transformer Output in Volt-Amperes. A figure used to determine the size of the CCT and CCR needed.

24. OUTPUT AMMETER

Measures the current flowing in an output lead of the generator.

25. REVERSE POWER RELAY

A relay with a wattmeter movement that senses the direction of power flow. If the engine of one of the paralleled plants stops, power will flow into the generator and the generator acts as a motor to drive the disabled plant. A reverse power relay can prevent this by sensing the reverse power and then disconnecting the disabled plant.

SECTION II
THEORY OF PARALLEL AC GENERATOR OPERATION

A. PURPOSE OF PARALLEL OPERATION

The purpose of paralleling power sources is:

1. To add to the power handling capacity of existing electric plants.
2. To increase reliability of the system by using two or more smaller electric plants rather than one larger unit.
3. To handle short duration peak loads to avoid higher "demand" rates levied by commercial power companies.

B. REQUIREMENTS OF PARALLEL OPERATION

1. An "operating" power source is assumed to be in existence. It may be either a commercial power line (utility bus) or a separate electric plant.
2. Each electric plant must have the proper controls and instruments. These include governor speed (frequency) and droop adjustments, generator voltage controls, cross current compensation circuit, meters for checking results of adjustments, synchronizing lights, and switching facilities.
3. It is possible to parallel electric plants of different manufacturers, provided the project is evaluated by an engineer who is familiar with paralleling problems.

C. PROBLEMS OF PARALLEL OPERATION

1. Synchronization: Fig. 1 illustrates the voltage wave forms of two electric plants. Fig. 2 illustrates the resultant voltage that is produced by the two plants at the corresponding times represented in Fig. 1. Note that at points A and C where the two waves coincide, the voltage approaches zero and at point B where the two waves are opposed, the voltage is highest, approaching twice the rated voltage.

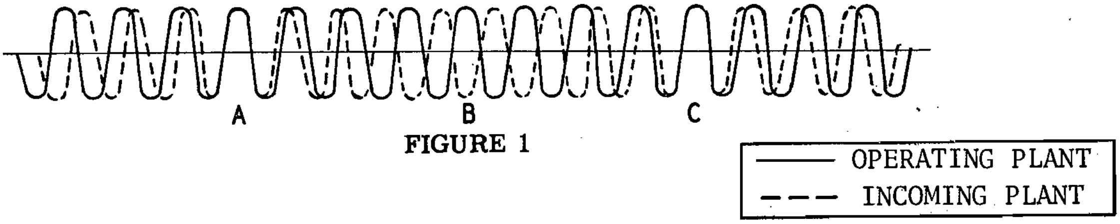


FIGURE 1

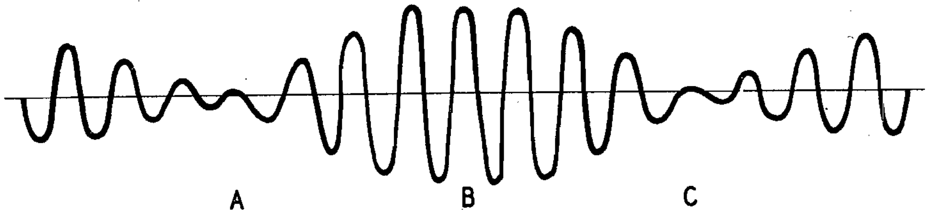


FIGURE 2

Synchronizing lights should be used to indicate that the wave forms are close enough together to permit paralleling. When connected as in Fig. 3, the lights will be dark when the voltage is lowest and bright when the voltage is highest.

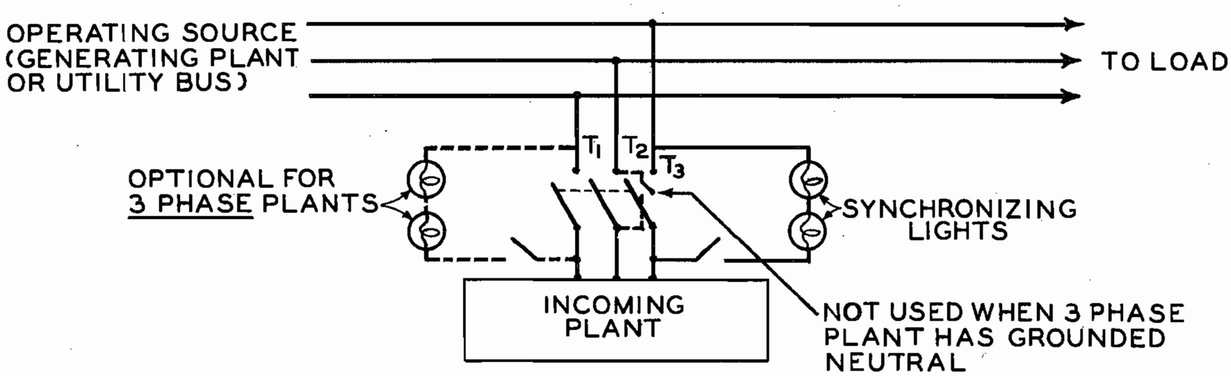


FIGURE 3

On three phase systems, an additional set of synchronizing lights can be used to assure proper phase sequence. The phase sequence must be the same between operating and incoming plants. Any attempt to parallel out-of-phase plants will result in severe damage. Refer to Section III, Instructions.

2. Switching Connection: Connection or paralleling of the incoming plant with the operating source should take place at synchronization as indicated by the dark period of the synchronizing lamps. Switching may be either automatic or manual. Manual switching requires the attention of a competent operator. Special equipment is required for automatic switching. When switched, the two plants are electrically locked together so that any speed change affects both plants just as though they were mechanically coupled.

3. Active Power: The active power a generating plant supplies is determined by the engine power developed. Because engine power is controlled (within design limits) by its governor, successful paralleling demands that each governor respond to load requirements equally. Therefore, it is important that the governors be pre-adjusted for the same speed droop.

   Average speed droop, from no-load to full-load, is approximately 2 cycles (60 cps for an 1800 rpm plant). A slightly greater droop is sometimes necessary to prevent "hunting" of paralleled plants.

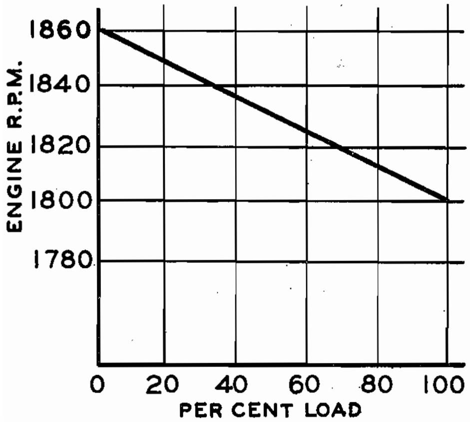


FIGURE 4

When paralleled, the two plants operate at the same speed, but the incoming plant governor may need to be adjusted for increased power, to assume more of the load.

A wattmeter on each plant is the best indicator of proper load sharing.
NOTE: An output ammeter can be used but will be more complicated to use and less accurate.
Adjust the speed of the incoming plant so that each plant's wattmeter reads in proportion to the plant's rated output.

For example, two 50 KW plants connected to a load of 80 KW should be adjusted to readings of 40 KW on each plant. A 60 KW plant and a 30 KW plant should be adjusted to readings of 53.5 KW and 26.5 KW, respectively. If speed droop has been properly pre-adjusted, each plant will then carry its proper share of the active power load, regardless of changes in the common load.

4. Reactive Power: Successful parallel operation requires that each plant carry its share of the reactive power as well as the active power. This means that each plant must have the same field excitation or internal voltage. If they are not the same, cross currents are set up between the two plants. The additional loading and heating effect limits the active power output of the plant having the higher excitation. Fig. 5 and 6 show the effects of differences in internal voltages.

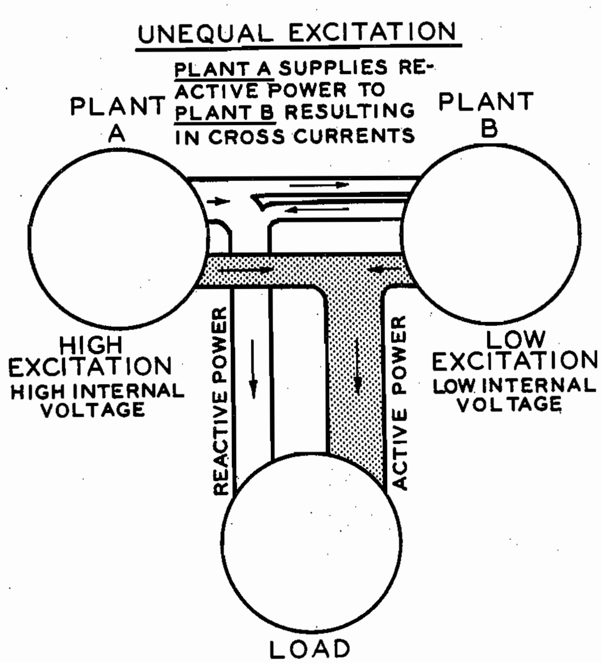


FIGURE 5

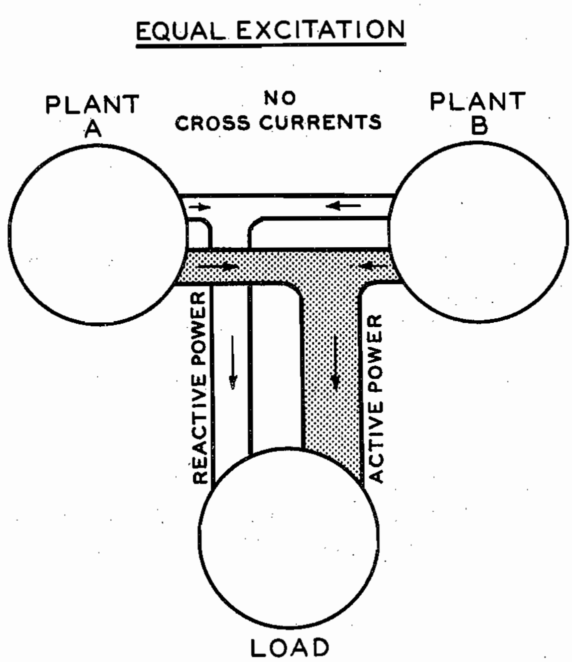


FIGURE 6

5. Cross Current Compensation -
Because each plant has different regulation characteristics, cross currents may occur as the load changes. To compensate for the different characteristics, a cross current circuit is added to cause the line voltage of each plant to droop as the reactive power increases.

This cross current circuit produces a voltage droop in the voltage regulator circuit to lower the internal voltage of the plant.

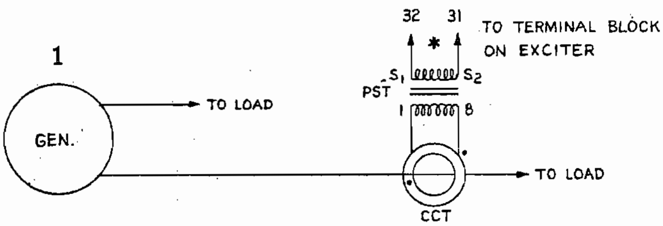
The cross current compensation circuit will cause the paralleled plants to have poorer output regulation (by the percentage of droop), but this loss in the quality of regulation is fully justified by the gain in reactive power division at all load conditions. A shorting switch should be provided to make the compensation circuit inoperative and thus improve the regulation during single plant operation.

6. Protective Devices -
Plants consistently paralleled should be protected from possible damage by safety devices. A reverse power relay will shut down both plants in the event one loses engine power. This is especially important when the connected load is less than the individual rating of either plant. If the engine of one should fail, it would continue to be turned because its generator would act as a synchronous motor energized by the operating plant. The serious consequences of forcing such a "dead" engine are obvious.

Standard protective devices, such as high water temperature and low oil pressure cutouts etc. can be easily rewired so that a dangerous situation on one plant will shut down both plants.

WIRING DIAGRAMS FOR CROSS CURRENT COMPENSATION

1



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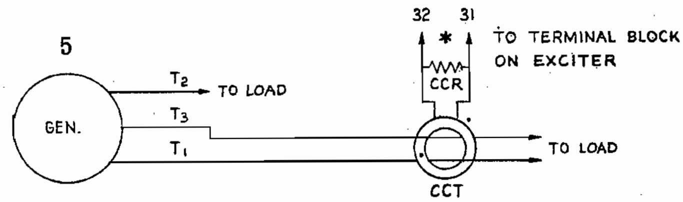

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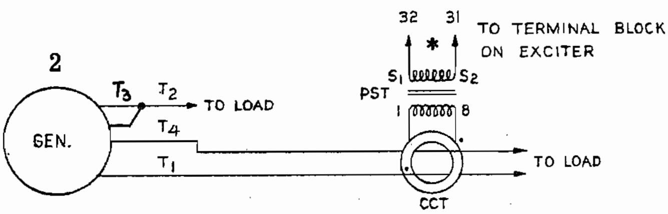

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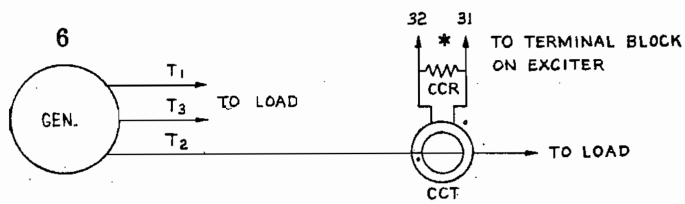

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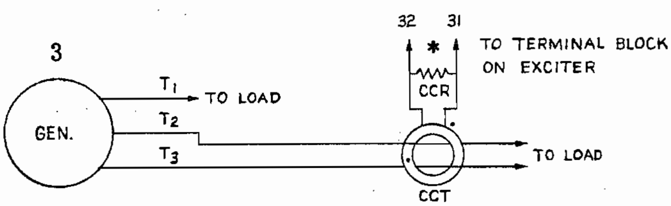

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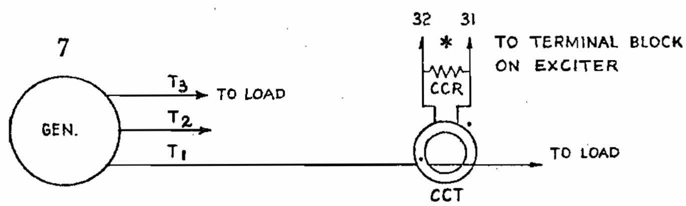

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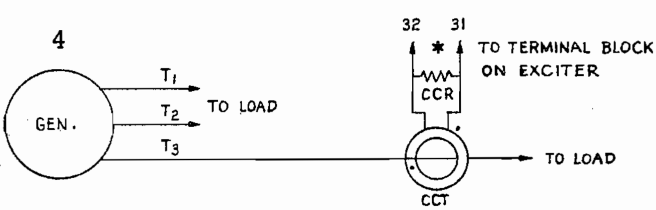

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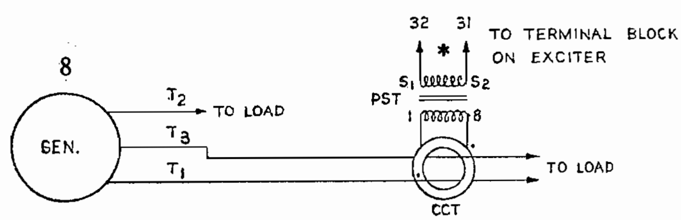


*Jumper strap between terminals 31-32 on exciter must be removed when connecting CCT into circuit.

CCR NOTE
To prevent resistance changes in CCR, from self heating, the resistor should have a wattage rating of approximately twice its actual power use.

CROSS CURRENT COMPENSATION DATA

GENERATOR						CROSS CURRENT TRANSFORMER									RESISTOR	
RATING AT .8 P.F.						PRI TURNS/	TOTAL PRI	EFFECTIVE PRI		Isec. FULL	Esec. FULL	FULL LOAD	INSTRU. RATING	ONAN PART	ADJ. TO	REC. SIZE
KW	VOLTS	PHASES	WIRES	AMPS	DIAG	LEAD	TURNS	NI	RATIO	LOAD	LOAD	BURDEN	BURDEN	NUMBER	OHMS	(2)
15	120	1	2	156	1	1	1	156	150/5	5.2A			5VA	302B497	(3)	
15	240	1	2	78	1	2	2	156	150/5	5.2A			5VA	302B497	(3)	
15	120/240	1	3	78	2	1	2	156	150/5	5.2A			5VA	302B497	(3).	
15	120/208	3	4	52	3	3	6	270	300/5	4.5A	8V	36VA	10VA	302B513	1.78	↑
15	277/480	3	4	22.6	3	6	12	234	250/5	4.7A	8V	37.6VA	10VA	302B617	1.7	2.5
15	120/240 (1)	3	4 Δ	45	4	6	6	270	300/5	4.5A	8V	36VA	10VA	302B513	1.78	OHM
15	480	3	3	22.5	3	6	12	234	250/5	4.7A	8V	37.6VA	10VA	302B617	1.7	ADJ.
15	240/480 (1)	3	4 Δ	22.5	4	12	12	270	300/5	4.5A	8V	36VA	10VA	302B513	1.78	75
15	220/380	3	4	28.4	3	6	12	295	300/5	4.9A	8V	39.3VA	10VA	302B513	1.63	WATT
15	347/600	3	3	18	3	9	18	295	300/5	4.7A	8V	37.6VA	10VA	302B513	1.7	↓
25	120	1	2	260	1	1	1	260	250/5	5.2A			5VA	302B616	(3)	
25	240	1	2	130	1	2	2	260	250/5	5.2			5VA	302B616	(3)	
25	120/240	1	3	130	2	1	2	260	250/5	5.2A			5VA	302B616	(3)	
25	120/208	3	4	87	3	2	4	300	300/5	5.0A	8V	40.0VA	10VA	302B513	1.6	↑
25	277/480	3	4	37	3	4	8	256	250/5	5.1A	8V	41.0VA	10VA	302B617	1.57	2.5
25	120/240 (1)	3	4 Δ	75	4	4	4	300	300/5	5.0A	8V	40.0VA	10VA	302B513	1.6	OHM
25	480	3	3	37	3	4	8	256	250/5	5.1A	8V	41.0	10VA	302B617	1.57	ADJ.
25	240/480 (1)	3	4 Δ	37	4	8	8	296	300/5	4.9A	8V	39.2VA	10VA	302B513	1.63	75
25	220/380	3	4	47	3	3	6	243	250/5	4.9A	8V	39. VA	10VA	302B617	1.6	WATT
25	347/600	3	3	30	3	6	12	312	300/5	5.2A	8V	41.6VA	10VA	302B513	1.54	↓

(1) DELTA CENTER TAPPED

(2) THIS IS A SUGGESTED VALUE TO COVER THE Isec FULL LOAD AND SUGGESTED RESISTANCE. CHOOSE RESISTOR FOR MAX I^2R

(3) USE PHASE SHIFT TRANSFORMER ONAN 302B462 (ELECTROMAGNETIC IND. R-120 OR EQUIVALENT)

(4) USE PHASE SHIFT TRANSFORMER (ELECTROMAGNETIC IND. R-240 OR EQUIVALENT)

CROSS CURRENT COMPENSATION DATA

GENERATOR						CROSS CURRENT TRANSFORMER									RESISTOR	
RATING AT .8 P.F.						PRI TURNS/	TOTAL PRI	EFFECTIVE PRI		Isec FULL	Esec FULL	FULL LOAD	INSTRU. RATING	ONAN PART	ADJ. TO	REC. SIZE
KW	VOLTS	PHASES	WIRES	AMPS	DIAG	LEAD	TURNS	NI	RATIO	LOAD	LOAD	BURDEN	BURDEN	NUMBER	OHMS	(2)
40	120	1	2	417	1	1	1	416	500/5	4.16A			5VA	302B438	(3)	
40	240	1	2	208	1	1	1	208	250/5	4.16A			5VA		(3)	
40	120/240	1	3	208	2	1	2	416	500/5	4.16A			5VA	302B438	(3)	
40	120/208	3	4	139	3	1	2	240	250/5	4.8A	8V	38.4VA	10VA	302B584	1.67	↑
40	277/480	3	4	60	3	3	6	312	300/5	5.2A	8V	41.6VA	10VA	302B513	1.54	2.5
40	120/240 (1)	3	4 Δ	120	4	2	2	240	250/5	4.8A	8V	38.4VA	10VA	302B617	1.67	OHM
40	480	3	3	60	3	3	6	312	300/5	5.2A	8V	41.6VA	10VA	302B513	1.54	ADJ
40	240/480 (1)	3	4 Δ	60	4	4	4	240	250/5	4.8A	8V	38.4VA	10VA	302B617	1.67	75
40	220/380	3	4	76	3	2	4	262	250/5	5.22A	8V	41.8VA	10VA	302B617	1.53	WATT
40	347/600	3	3	48	3	3	6	249	250/5	4.98A	8V	39.9VA	10VA	302B617	1.6	↓
50	120	1	1	521	1	1	1	521	500/5	5.2A			5VA	302B436	(3)	
50	240	1	1	260	1	1	1	260	250/5	5.2A			5VA	302B584	(3)	
50	120/240	1	2	260	2	1	2	520	500/5	5.2A			5VA	302B438	(3)	
52.5	120/208	3	4	182	3	1	2	315	400/5	3.94A	8	31.5VA	10VA		2.03	↑
52.5	277/480	3	4	79	3	2	4	274	300/5	4.57A	8	36.6VA	10VA	302B513	1.75	2.5
52.5	120/240 (1)	3	4 Δ	158	4	2	2	316	300/5	5.27A	8	42.2VA	10VA	302B513	1.52	OHM
52.5	480	3	3	79	3	2	4	274	300/5	4.57A	8	36.6VA	10VA	302B513	1.75	ADJ.
52.5	240/480 (1)	3	4 Δ	79	4	3	3	237	250/5	4.78A	8	38.2VA	10VA	302B617	1.67	75
52.5	230/380	3	4	95	3	2	4	328	400/5	4.1A	8	32.8VA	10VA	302B646	1.95	WATT
52.5	347/600	3	3	63	3	2	4	218	250/5	4.37A	8	35 VA	10VA	302B617	1.83	↓
62.5	120/208	3	4	217	3	1	2	375	400/5	4.69A	8	37.5VA	10VA	302B646	1.71	↑
62.5	277/480	3	4	94	3	2	2	327	400/5	4.08A	8	32.6VA	10VA	302B646	1.96	2.5
62.5	120/240 (1)	3	4 Δ	188	4	2	2	376	400/5	4.7A	8	37.6VA	10VA	302B646	1.70	OHM
62.5	480	3	3	94	3	2	4	326	400/5	4.08A	8	32.6VA	10VA	302B646	1.96	ADJ.
62.5	240/480 (1)	3	4 Δ	94	4	3	3	282	300/5	4.7A	8	37.6VA	10VA	302B513	1.70	75
62.5	220/380	3	4	118	3	2	4	408	400/5	5.1A	8	40.8VA	10VA	302B646	1.59	WATT
62.5	347/600	3	3	75	3	2	4	260	300/5	4.3A	8	34.4VA	10VA	302B513	1.86	↓

(1) DELTA CENTER TAPPED

(2) THIS IS A SUGGESTED VALUE TO COVER THE Isec FULL LOAD AND SUGGESTED RESISTANCE. CHOOSE RESISTOR FOR MAX I^2R

(3) USE PHASE SHIFT TRANSFORMER ONAN 302B462 (ELECTROMAGNETIC IND. INC. R-120 OR EQUIVALENT)

(4) USE PHASE SHIFT TRANSFORMER (ELECTROMAGNETIC IND. INC. R-240 OR EQUIVALENT)

CROSS CURRENT COMPENSATION DATA

GENERATOR						CROSS CURRENT TRANSFORMER									RESISTOR	
RATING AT .8 P.F.																
KW	VOLTS	PHASES	WIRES	AMPS	DIAG	PRI TURNS/ LEAD	TOTAL PRI TURNS	EFFECTIVE PRI NI	RATIO	Isec FULL LOAD	Esec FULL LOAD	FULL LOAD BURDEN	INSTRU. RATING BURDEN	ONAN PART NUMBER	ADJ. TO OHMS	REC. SIZE (2)
75	240	1	2	391	1	1	1	391	400/5	4.89A			5VA	302B609	(4)	
75	120/240	1	3	391	8 (5)	1	2	782	800/5	4.89A			5VA	302B508	(4)	
75	120/208	3	4	260	3	1	2	450	500/5	4.5A	8	36VA	10VA	302B531	1.78	↑
75	277/480	3	4	113	3	2	4	390	400/5	4.88A	8	39VA	10VA	302B646	1.64	2.5
75	120/240 (1)	3	4 Δ	225	4	1	1	225	250/5	4.5A	8	36VA	10VA	302B617	1.78	OHM
75	480	3	3	113	3	2	4	390	400/5	4.88A	8	39VA	10VA	302B646	1.64	ADJ.
75	240/480 (1)	3	4 Δ	113	4	2	2	226	300/5	3.77A	8	30.2VA	10VA	302B513	2.12	75
75	220/380	3	4	142	3	1	2	246	250/5	4.92A	8	39.4VA	10VA	302B617	1.63	WATT
75	347/600	3	3	90	3	2	4	312	300/5	5.2A	8	41.6VA	10VA	302B513	1.54	↓
100	240	1	2	521	1	1	1	521	500/5	5.21A			5VA	302B438	(4)	
100	120/240	1	3	521	8	1	2	1042	1000/5	5.21A			5VA	302B459	(4)	
100	120/208	3	4	347	6	2	2	694	750/5	4.63A	13.9	60.3VA	15VA		3.0	↑
100	277/480	3	4	150	4	4	4	600	600/5	5.0A	16	80.0VA	15VA		3.2	4
100	120/240 (1)	3	4 Δ	300	6	2	2	600	600/5	5.0A	16	80.0VA	15VA		3.2	OHM
100	240/480 (1)	3	4 Δ	150	4	4	4	600	600/5	5.0A	16	80.0VA	15VA		3.2	ADJ.
100	220/380	3	4	189	7	2	4	654	750/5	4.36A	14.6	63.6	15VA		3.35	100
100	240/416	3	4	174	6	4	4	696	750/5	4.64A	16	74.2	15VA		3.45	WATT
100	347/600	3	3	120	3	3	6	624	600/5	5.2A	16	83.2VA	15VA		3.08	↓
125	240	1	2	651	1	1	1	651	750/5	4.34A			5VA	302B625	(4)	
125	120/240	1	3	651	8	2	1	1302	1500/5	4.34A			5VA	302B644	(4)	
125	120/208	3	4	434	6	1	1	434	500/5	4.34A	13.9	60.3VA	15VA		3.2	↑
125	277/480	3	4	188	4	3	3	564	600/5	4.7A	16	75.2VA	15VA		3.4	4
125	120/240 (1)	3	4 Δ	375	6	2	2	750	750/5	5.0A	16	75VA	15VA		3.2	OHM
125	240/480 (1)	3	4 Δ	188	4	3	3	564	600/5	4.7A	16	75.2VA	15VA		3.4	ADJ.
125	220/380	3	4	237	7	2	4	820	800/5	5.13A	14.6	74.8VA	15VA		2.85	100
125	240/416	3	4	217	6	3	3	650	750/5	4.34A	16	69.4VA	15VA		3.69	WATT
125	347/600	3	3	150	3	2	4	520	500/5	5.2A	16	83.2VA	15VA		3.07	↓

(1) DELTA CENTER TAPPED

(2) THIS IS A SUGGESTED VALUE TO COVER THE Isec FULL LOAD AND SUGGESTED RESISTANCE. CHOOSE RESISTOR FOR MAX I^2R

(3) USE PHASE SHIFT TRANSFORMER ONAN 302B464 (ELECTROMAGNETIC IND. INC. R-120 OR EQUIVALENT)

(4) USE PHASE SHIFT TRANSFORMER (ELECTROMAGNETIC IND. INC. R-240 OR EQUIVALENT)

(5) FOR UNITY POWER FACTOR GENERATING SET, USE DIAG 2

CROSS CURRENT COMPENSATION DATA

GENERATOR						CROSS CURRENT TRANSFORMER									RESISTOR	
RATING AT .8 P.F.																
KW	VOLTS	PHASES	WIRES	AMPS	DIAG	PRI TURNS/ LEAD	TOTAL PRI TURNS	EFFECTIVE PRI NI	RATIO	Isec FULL LOAD	Esec FULL LOAD	FULL LOAD BURDEN	INSTRU. RATING BURDEN	ONAN PART NUMBER	ADJ. TO OHMS	REC. SIZE (2)
150	120/208	3	4	521	6	1	1	521	500/5	5.2A	13.9	72.3VA	15VA		2.67	↑
150	277/480	3	4	226	4	2	2	452	500/5	4.52A	16	72.3	15VA		3.54	4
150	120/240 (1)	3	4 Δ	451	6	1	1	451	500/5	4.51A	16	72.2	15VA		3.55	OHM
150	240/480 (1)	3	4 Δ	225	4	2	2	450	500/5	4.5A	16	72VA	15VA		3.56	ADJ.
150	220/380	3	4	284	7	1	2	491	500/5	4.91A	14.6	71.7VA	15VA		2.97	100
150	240/416	3	4	260	6	2	2	520	500/5	5.2A	16	83.2VA	15VA		3.07	WATT
150	347/600	3	3	180	3	2	4	622	600/5	5.18A	16	82.9VA	15VA		3.09	↓
175	120/208	3	4	608	6	1	1	608	600/5	5.07A	13.9V	70.5VA	15VA		2.74	↑
175	277/480	3	4	263	4	2	2	526	600/5	4.38A	16	70VA	15VA		3.65	4
175	120/240 (1)	3	4 Δ	526	6	1	1	526	600/5	4.38A	16	70VA	15VA		3.65	OHM
175	240/480 (1)	3	4 Δ	263	4	2	2	526	600/5	4.38A	16	70VA	15VA		3.65	ADJ.
175	220/380	3	4	331	7	1	2	573	600/5	4.8A	14.6	70VA	15VA		3.04	100
175	240/416	3	4	304	6	2	2	608	600/5	5.06A	16	70.6VA	15VA		3.16	WATT
175	347/600	3	3	210	3	2	4	726	800/5	4.54A	16	72.6	15VA		3.52	↓
200	120/208	3	4	694	6	1	1	694	750/5	4.63A	13.9V	64.4VA	15VA		3.0	↑
200	277/480	3	4	301	4	2	2	602	600/5	5.0A	16	80VA	15VA		3.2	4
200	120/240 (1)	3	4 Δ	601	6	1	1	601	600/5	5.0A	16	80VA	15VA		3.2	OHM
200	240/480 (1)	3	4 Δ	300	4	2	2	600	600/5	5.0A	16	80VA	15VA		3.2	ADJ.
200	220/380	3	4	379	7	1	2	656	750/5	4.37A	14.6	63.8VA	15VA		3.3	100
200	240/416	3	4	347	6	2	2	694	750/5	4.63	13.9	64.4	15VA		3.0	WATT
200	347/600	3	3	240	3	2	4	830	800/5	5.19A	16	83.0VA	15VA		3.1	↓

(1) DELTA CENTER TAPPED

(2) THIS IS A SUGGESTED VALUE TO COVER THE Isec FULL LOAD AND SUGGESTED RESISTANCE. CHOOSE RESISTOR FOR MAX I^2R

(3) USE PHASE SHIFT TRANSFORMER ONAN 302B462 (ELECTROMAGNETIC INC. INC. R-120 OR EQUIVALENT)

(4) USE PHASE SHIFT TRANSFORMER (ELECTROMAGNETIC IND. INC. R-240 OR EQUIVALENT)

CROSS CURRENT COMPENSATION DATA

GENERATOR: RATING AT .8 P.F. KW	VOLTS	PHASES	WIRES	AMPS	DIAG	CROSS CURRENT TRANSFORMER: PRI TURNS/ LEAD	TOTAL PRI TURNS	EFFECTIVE PRI NI	RATIO	Isec FULL LOAD	Esec FULL LOAD	FULL LOAD BURDEN	INSTRU. RATING BURDEN	ONAN PART NUMBER	RESISTOR: OHMS	WATTS (2)
250	120/208	3	4	868	6	1	1	868	1000/5	4.34	13.9	60.4	15 VA		3.2	
250	277/480	3	4	375	4	2	2	750	750/5	5.0	16	80	15 VA		3.2	4
250	120/240 (1)	3	4Δ	752	6	1	1	752	750/5	5.01	16	81.5	15 VA		3.2	OHM
250	240/480 (1)	3	4Δ	375	4	2	2	750	750/5	5.0	16	80	15 VA		3.2	ADJ
250	220/380	3	4	475	7	1	2	822	800/5	5.13	14.6	75	15 VA		2.84	100
250	240/416	3	4	434	6	2	2	752	750/5	5.1	13.9	81.5	15 VA		2.73	WATT
250	347/600	3	4	303	3	2	4	1050	1000/5	5.25	16	84	15 VA		3.05	
300	120/208	3	4	1040	4	1	1	1040	1000/5	5.2	8	41.6	5 VA	302B589	1.54	
300	277/480	3	4	450	4	1	1	450	500/5	4.5	8	36	5 VA	302B438	1.78	2
300	120/240 (1)	3	4Δ	903	4	1	1	903	1000/5	4.51	8	36	5 VA	302B589	1.78	OHM
300	240/480 (1)	3	4Δ	450	4	1	1	450	500/5	4.5	8	36	5 VA	302B438	1.78	ADJ
300	220/380	3	4	570	4	1	1	570	600/5	4.75	8	38	5 VA	302B706	1.69	75
300	240/416	3	4	522	4	1	1	522	500/5	5.22	8	41.7	5 VA	302B438	1.53	WATT
300	347/600	3	4	360	4	1	1	360	400/5	4.5	8	36	5 VA	302B609	1.78	
350	120/208	3	4	1220	4	1	1	1220	1200/5	5.08	8	40.7	5 VA	302B643	1.58	
350	277/480	3	4	528	4	1	1	528	500/5	5.28	8	42.3	5 VA	302B438	1.52	2.5
350	120/240 (1)	3	4Δ	1048	4	1	1	1048	1000/5	5.24	8	41.9	5 VA	302B589	1.53	OHM
350	240/480 (1)	3	4Δ	528	4	1	1	528	500/5	5.28	8	42.3	5 VA	302B438	1.52	ADJ
350	220/380	3	4	668	4	1	1	668	750/5	4.44	8	35.5	5 VA	302B625	1.83	75
350	240/416	3	4	608	4	1	1	608	600/5	5.07	8	40.6	5 VA	302B706	1.58	WATT
350	347/600	3	4	422	4	1	1	422	400/5	5.27	8	42.2	5 VA	302B609	1.52	
400	120/208	3	4	1390	4	1	1	1390	1500/5	4.63	8	37	5 VA	302B644	1.73	
400	277/480	3	4	602	4	1	1	602	600/5	5.02	8	40.2	5 VA	302B706	1.6	2.5
400	120/240 (1)	3	4Δ	1200	4	1	1	1201	1200/5	5.0	8	40	5 VA	302B643	1.6	OHM
400	240/480 (1)	3	4Δ	602	4	1	1	602	600/5	5.02	8	40.2	5 VA	302B706	1.6	ADJ
400	220/380	3	4	760	4	1	1	760	750/5	5.07	8	40.5	5 VA	302B625	1.59	75
400	240/416	3	4	695	4	1	1	695	750/5	4.63	8	37	5 VA	302B625	1.73	WATT
400	347/600	3	4	483	4	1	1	483	500/5	4.83	8	38.6	5 VA	302B438	1.66	

(1) DELTA CENTER TAPPED

(2) THIS IS A SUGGESTED VALUE TO COVER THE Isec FULL LOAD AND SUGGESTED RESISTANCE. CHOOSE RESISTOR FOR MAX I^2R

(3) USE PHASE SHIFT TRANSFORMER ONAN 302B462 (ELECTROMAGNETIC IND. INC. R-120 OR EQUIVALENT)

(4) USE PHASE SHIFT TRANSFORMER (ELECTROMAGNETIC IND. INC. R-240 OR EQUIVALENT)

SECTION III
SUGGESTED TEST PROCEDURE FOR PARALLELING PLANTS

1. Perform standard tests on single units.

   a. Follow standard test procedure to test each unit before attempting to parallel.
   b. Pay particular attention to the phase rotation, speed and voltage regulation.

2. Check cross-current compensation on single units.

   a. Place the cross-current switch in the single position.
   b. Load the individual unit to full load at .8 power factor.
   c. Switch the cross-current switch to the parallel position and observe output voltage. The voltage should drop 4% on each unit. If voltage goes up, reverse the secondary leads on the cross-current transformer.

3. Synchronize units.

   a. Start both units and close the load breaker on unit #1.
   b. Adjust the speed of both units to the same frequency.
   c. Adjust the output of both units to the same voltage.
   d. Re-adjust the speed of unit #2 until the synchronizing lamps light and go dark very slowly indicating that they are synchronized.

4. Parallel units at no load.

   a. Close unit #2 load breaker when the synchronizing lamps go dark.

5. Reduce cross currents.

   a. At 20% load, adjust the speed and voltage of unit #2 for minimum total current. When the sum of the output currents are at the lowest obtainable, then the cross-currents are at a minimum.

6. Check load division.

   a. Apply a 20% load and adjust the speed and voltage so that each unit carries 10% of its rating with a minimum cross-current.
   b. Without further adjustments, vary the load in steps from 0 - 100% of their combined load rating.
   c. Record KW and KVA outputs of each unit at each load step.

   The difference in KW output of the units at any load step from 20% to 100% rating should be less than 10% of their combined full load rating.

   The difference in KVA output of the units at any load step from 0 - 100% should be less than 10% of the individual unit full load rating.

7. Shutdown.

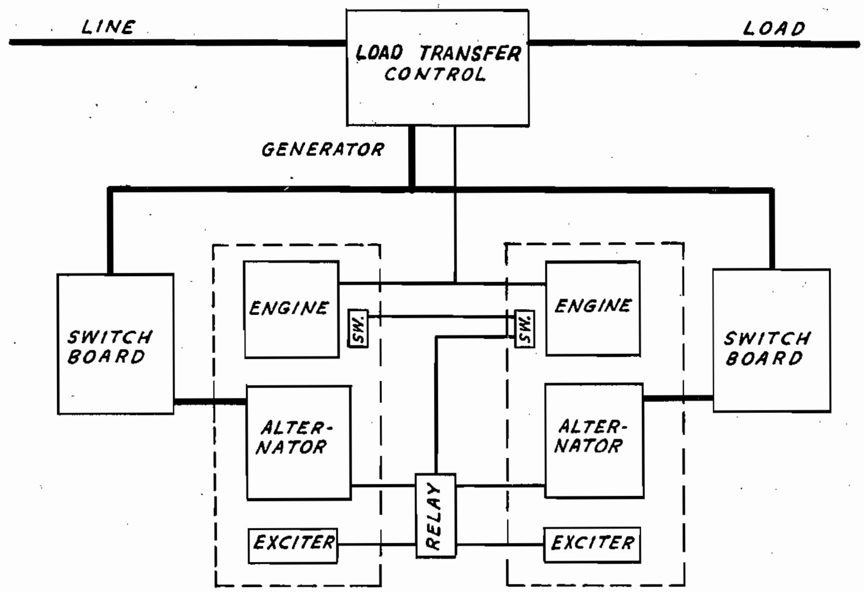
   a. Reduce the total load to less than the full load rating of one unit.
   b. Open the load breaker on the unit to be shut down first.
   c. Stop the unit.
   d. Stop the other unit.

SECTION IV
EXCITER PARALLELING

The following block diagrams show how to automatically parallel two, three, or four electric plants in conjunction with a load transfer control. An interruption of commercial power causes the load transfer control to energize the start circuit on each of the electric plants. The engines crank, start, and come up to operating speed.

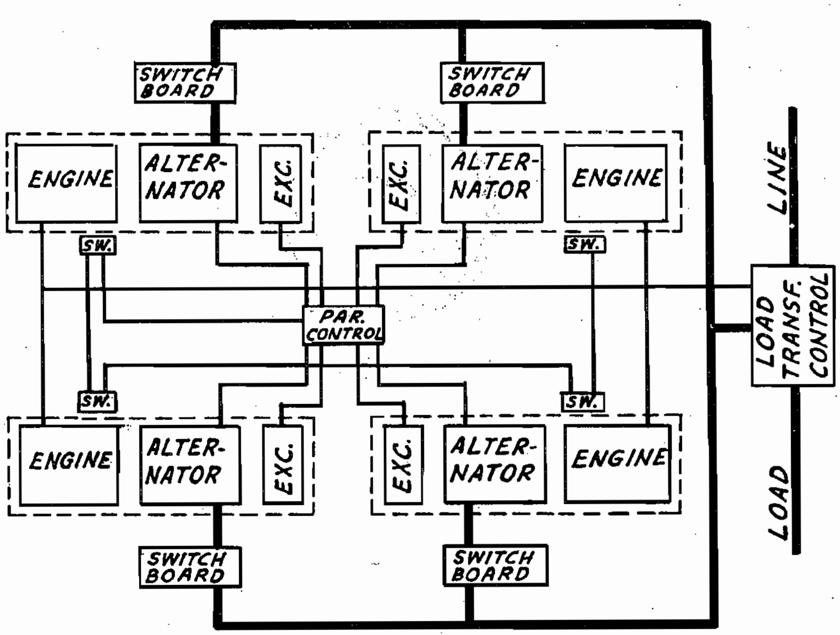
A centrifugal switch on each engine senses that the engine has reached operating speed. All the series connected centrifugal switches must close to energize a relay in the paralleling control. This relay closes the circuits between the alternator and exciter of each statically excited electric plant, or between the regulator and the exciter on each brushless electric plant. With these circuits closed, the exciters build up and supply field power for the alternator. The alternators connected together, pull into synchronization at low voltage as the excitation is building up and, consequently, the out-of-phase period is for a short time and at very low power levels. This has no adverse effect upon the electric plants. The power from each alternator feeds standard paralleling switchboards with shunt trip breakers, reverse power relays, cross-current compensation, and indicating instruments. The load transfer control transfers the load over to the electric plants until power is resumed on the utility line.

In the event of the malfunction of one of the electric plants, the appropriate safety switch will shut off the engine. The reverse power relay in the switchboard will energize the shunt trip in the circuit breaker, and remove the alternator from the bus. The centrifugal switch on the engine will open to drop the relay in the automatic paralleling control to remove excitation from the remaining machines. A selector switch in the paralleling control can bypass the centrifugal switch on the disabled electric plant to permit automatic paralleling of the remaining units at reduced load. If the load is too great for the remaining electric plants their circuit breakers will trip. It will be necessary to remove load in order to resume operation. The units may be manually paralleled by resetting the circuit breakers reset, and the engines restarted again to accomplish the automatic paralleling.



AUTOMATIC PARALLELING STANDBY SYSTEMS

2 UNITS



AUTOMATIC PARALLELING STANDBY SYSTEMS

4 UNITS