



AC Generators

FAULT FINDING MANUAL

Self Excited and Permanent Magnet Excited Machines

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FAULT FINDING MANUAL

SECTION 1 - Recommended Metering And Test Instruments

SECTION 2 - Electrical Terminology

SECTION 3 - Fault Finding Method (A) All Machines

SECTION 4 - Fault Finding Self Excited Machines

SECTION 5 - Fault Finding Separately Excited Machines

SECTION 6 - Parallel Operation and Fault Finding ALL Machines

SECTION 1

Recommended Metering and Test Instruments

To successfully carry out the various test procedures suggested in this manual, certain test instruments are essential. The following lists detail the basic requirements in this respect.

It should be noted that in addition to these instruments a comprehensive kit of tools is also essential. For fault finding purposes this need not include any specialised tools.

ITEM 1 - THE MULTI METER

The multimeter is a comprehensive test instrument for measuring voltage, current and resistance. It should be capable of measuring the following ranges:-

Voltage A C	0-250-500-1000
Voltage D C	0-25-100-250
Amperes D C	0-10
Ohms D C Resistance	0-10K ohm or 0-2k ohm
	0-100k ohm or 0-20k ohm
	0-1 Megohm or 0-200k ohm

ITEM 2 - TACHOMETER

This instrument is for measuring the shaft speed of the alternator and should be capable of measuring speeds between 0 and 5000 revs. per minute.

A alternative to the tachometer is the frequency meter (see Section 2 on Frequency and Speed, for details). However the alternator must be generating its normal output voltage for this instrument to be accurate.

ITEM 3 - MEGGER

This instrument generates a voltage of 500 or 1000 volts, and is used to measure the resistance value of the insulation to earth (ground). It may be an electronic push button type, or a hand cranked generator type.

ITEM 4 - CLIP-ON AMMETER

Used to measure A C current only, it consists of a pair of calipers which are clipped around the conductor, and by means of a current transformer action, gives an indication of the amperes flowing in the conductor. Useful ranges to have on this meter are:-

A C Amps 0-10-50-100-250-500-1000

ITEM 5 - KELVIN BRIDGE - LOW RESISTANCE METER

These instruments are used to measure resistance values below 1.0 ohm. They are bulky, and expensive, but are the only means of accurately measuring very low resistances, such as main stator winding etc.

There are other methods of establishing if these windings are faulty, and these are included in the various test procedures, i.e Test method.

SECTION 2

Electrical Terminology and Resistances

Voltage and Current (Amperes)

An Alternator is designed to produce a voltage level suitable for the equipment or load which it is supplying. The control circuits are designed to maintain this voltage level as the load is increased or decreased.

Sudden large changes in loading will produce temporary changes in the voltage, and the control circuit is designed to recover to a stabilised condition as quickly as possible.

The current drawn from the alternator is determined by the amount of load connected to it. Current creates a temperature rise in the windings, hence the requirement for drawing air through the alternator by means of the fan. If the full load rated current is exceeded on any phase of the main stator windings, it will result in overheating in this winding. Similarly, any restriction in the flow of air through the machine will result in a rapid increase in the temperature of the windings.

FREQUENCY (Hz) and SPEED (RPM)

An alternator is a constant speed device, and should not be operated at speeds above 4% of the rated speed, or more than 1% below the rated speed.

Load changes will create temporary changes in the speed, but the engine must be capable of returning to the steady state condition within a few seconds.

The speed requirements for the alternator are determined by:-

- (a) The frequency (Hz) requirement of the load
- (b) The number of pole in the alternator, i.e. (rotor coils)

This can be shown more clearly in a chart:-

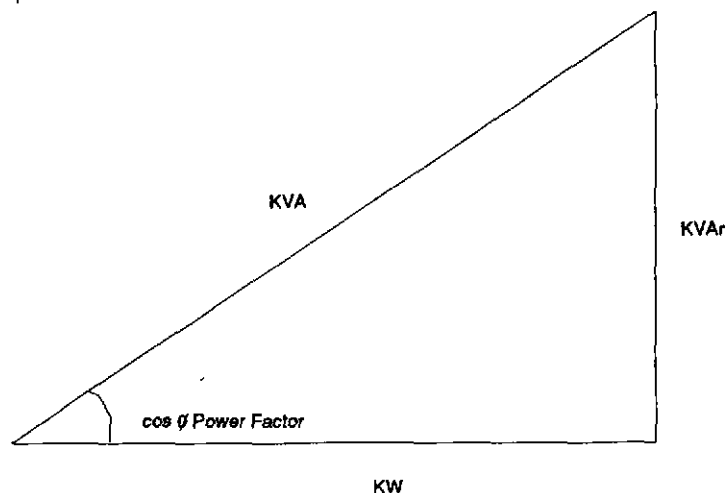
FREQUENCY (Hz)	SPEED(RPM)	NO.OF POLES (rotor coils)
50	1500	4
60	1800	4
50	1000	6
60	1200	6
50	3000	2
60	3600	2

From this chart, a simple formula is produced to calculate the speed from the frequency, or vice versa.

4 pole machine	1 cycle (Hz) = 30 R.P.M
6 pole machine	1 cycle (Hz) = 20 R.P.M.
2 pole machine	1 cycle (Hz) = 60 R.P.M.

KILOWATTS (kW) KILO VOLT AMPERES (kVA) and POWER FACTORS (P.F.)

For an alternator to supply power for a load of 1kW, the prime mover (engine) driving the alternator must produce approximately 1.5 horse power.



Kilowatts is calculated by the formula:-

$$\text{kW} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}{1000}$$

kVA (Kilo Volt Amperes) are calculated by the formula:-

$$\text{kVA} = \frac{\text{Volts} \times \text{Amperes}}{1000}$$

Both equations are multiplied by $\sqrt{3}$ (1.732) for a 3 phase machine.

POWER FACTOR

The Power Factor (p.f.) is a measure of wasted current which is produced by all inductive loads such as motors, transformers, (wound components)

The formula for calculating the Power Factor is:-

$$\text{P.F.} = \frac{\text{Kilowatts}}{\text{kVA}}$$

Purely resistive loading i.e. heating, lighting has a Power Factor of unity (1/1) and contains very little wattless current.

UNITY POWER FACTORS

An alternator will deliver continuously the rated full load current at any power factor between unity and 0.8. However, the prime mover driving the alternator is greatly affected by the power factor, and it is most important therefore, that this is taken into account when approaching the 3/4 to full load current levels.

As most full load ratings are quoted at 0.8PF., the kW rating of the engine may be 20% lower than the kVA rating of the alternator. A full load current at unity (1/1) Power Factor (kVA=kW) would in this case represent a 20% overload to the prime mover.

It must be remembered, therefore, that when the alternator is supplying a resistive load (heating and lighting), the engine may be delivering its full power at a current level approximately 20% below the full rated current of the alternator.

LAGGING POWER FACTOR

An alternator is designed to deliver the full load current at any power factor between unity and 0.8 lagging. Certain loads have a power factor below this figure e.g. welding transformers; auto-transformer start motors, and a de-rating of the full load is necessary at lower power factors.

LEADING POWER FACTOR

A leading power factor is produced by capacitive load e.g. fluorescent lighting, power factor correction capacitors. The latter is supplied by the Electricity Board to improve the customers lagging power factor, and the size for the capacitors are measured in kVAr (reactive).

This type of load presents problems with mains failure standby plants, as a purely capacitive load creates voltage instability, and produces very high transient voltages spikes when switched. The degree of instability is determined by the kVAr size of the capacitors to the kVA size of the alternator.

When the mains electricity supply fails, all motor load is disconnected by their individual cotactors. Subsequently, as the alternator takes the load it will mainly consist of lighting, and possibly the power factor correction capacitors. The alternator will see a very low leading power factor and may become unstable, or generate a high output voltage.

In order to prevent this situation, it is advisable to ensure that the power factor correction capacitors are switched OFF when the alternator takes the initial load.

Further advice in this respect may be obtained from NEWAGE if required.

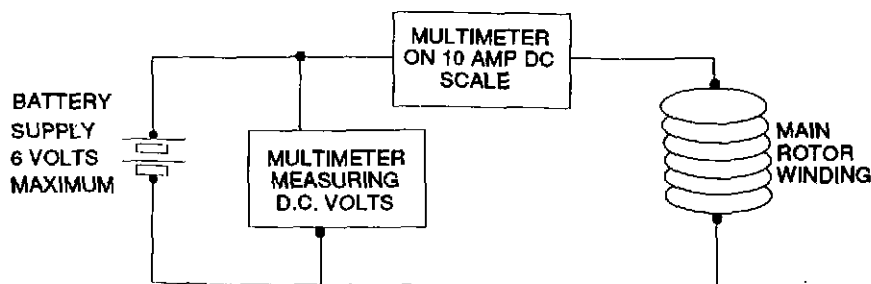
RESISTANCES - MEASURING COMPONENT VALUES

When fault finding it is necessary to measure the resistance values of components and windings, and compare them with known normal values, in order to locate the fault. The normal resistances of the windings are given in the winding resistance charts, in the machine handbook.

Resistances values above 10 ohms can be measured accurately with a multimeter. Between 1 and 5 ohms a multimeter has a limited accuracy, and other methods must be adopted.

RESISTANCE BETWEEN 1 AND 5 OHMS

The resistance value of a winding such as a brushless main rotor will be between 0.5 and 3 ohms. A multimeter may not give an accurate enough reading at these levels, and if a Wheatstone Bridge Resistance Meter is not available, an accurate measurement can be obtained by means of a battery supply with a multimeter in series on the 10 Amps D.C. range (most A.V.R meters have this current range).



Using 2-6 volt battery cells the resistance of the winding can be calculated i.e.

$$\frac{V \text{ (volts)}}{1 \text{ (amps)}} = \Omega \text{ (ohms)}$$

The resultant can be compared with the correct value given in the resistance charts, and this method can be used for any resistance greater than 1.0 ohm.

Below this value the current in the circuit could drain the battery, and it is therefore impractical to use this method.

VERY LOW RESISTANCE VALUES (BELOW 1.0 OHM)

Main stators ('C' range) and exciter rotors can be included in this category.

These values can only be accurately measured with a Kelvin Bridge Resistance Meter.

The probes are equipped with special spikes which penetrate the surface of the contact, ensuring accurate reading.

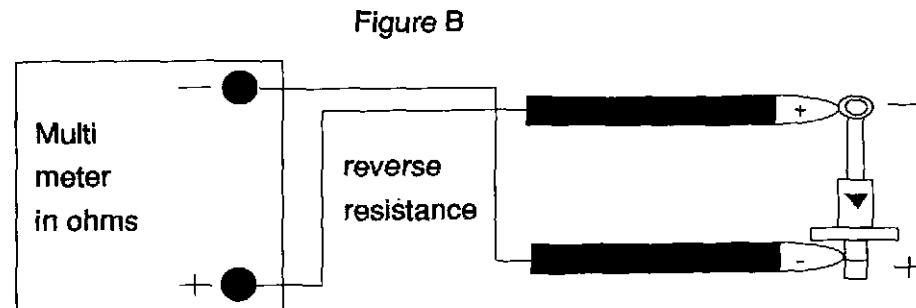
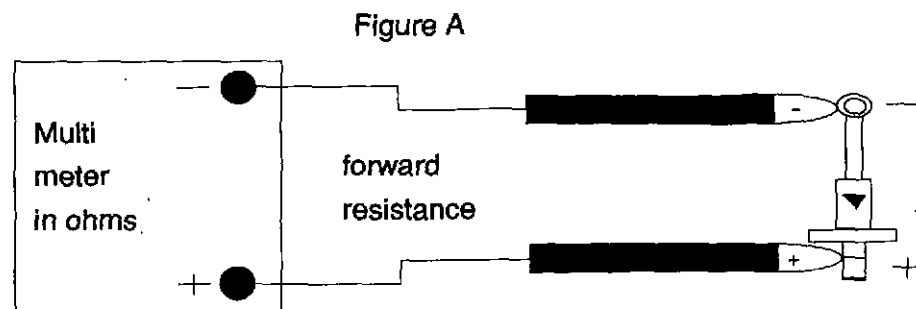
'C' range main stator windings can also be tested by means of separately exciting the machine (see Test Method A), thus partly eliminating the need to carry out this type of specialised instrument when trouble shooting.

DIODE AND THYRISTOR TESTING

THE DIODE

A Diode has two resistance values, forward and reverse, and these can be measured with a multimeter as shown in the diagram below, using the lowest resistance scale on the meter.

The forward resistance is being measured in Fig. A with the positive meter lead connected to the forward side of the diode.



NOTE; An electronic digital instrument will read true electron flow - hence the resistance polarity readings will be reverse of above. i.e. Forward and reverse readings will be reversed.

NOTE

The positive side of a diode is indicated by an arrow printed on the diode body.

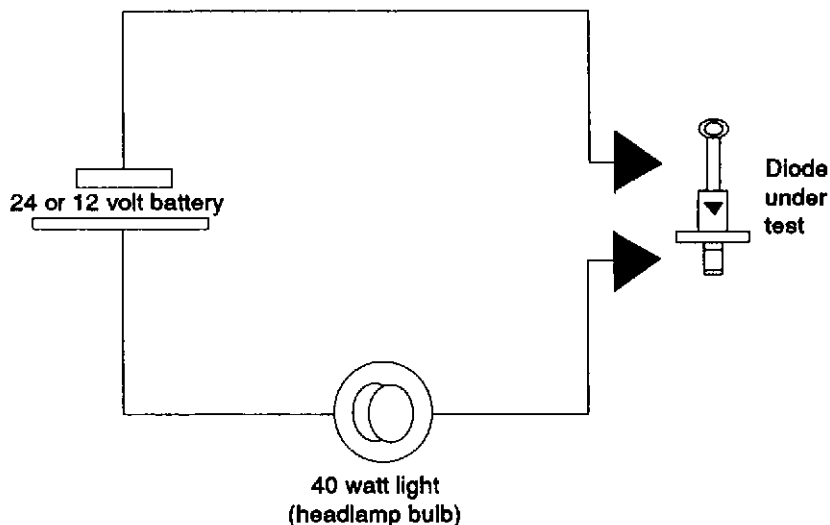
In Figure 'B' the meter leads have been reversed, and the reverse resistance is being measured.

The forward resistance varies considerably, depending on the impedance of the multimeter, and the diode type. Typical resistance would be between 20 and 100 ohms.

The reverse resistance must be much higher, and is usually in excess of 100k ohms, (100,000).

A digital electronic multimeter usually has a special diode test scale measuring electron flow and will indicate zero or infinity on the readout.

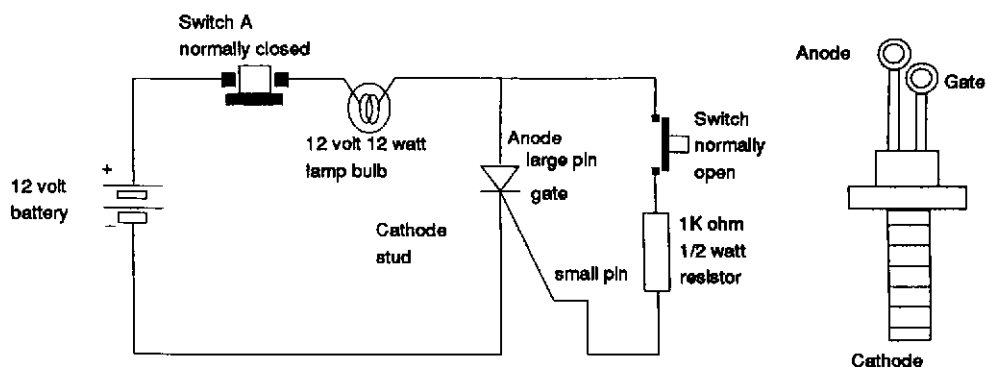
SIMPLE DIODE TEST CIRCUIT



A good diode will light in one direction, and no light when test leads are reversed on diode pin and base.

THE THYRISTOR

SIMPLE TEST CIRCUIT FOR THYRISTORS



TEST PROCEDURE

1. Connect the thyristor in circuit as shown.
2. Switch A Should be CLOSED. Switch B should be OPEN
3. If lamp lights immediately the thyristor is short circuit (faulty).
4. If lamp remains dark press switch B. Lamp should light and stay ON
5. Press switch A Lamp should go OFF, and stay OFF
Failure to operate as above indicates a faulty thristor.

RESISTANCE TEST METHOD

The thyristor can be checked using a multimeter, on the highest and lowest resistance scales.

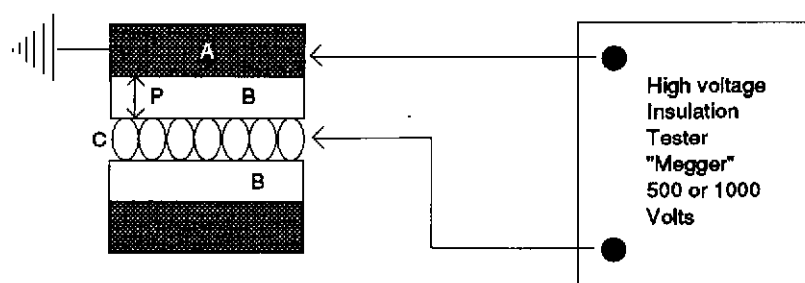
On the highest scale, check from the anode to the cathode gate pins.
There should be no deflection on the meter in either direction.

On the lowest scale, check from the cathode to the gate. The reading should be lower than 500 ohms, but higher than 20 ohms, in either direction.

A faulty thyristor will be short circuited across the anode and either pin, or short circuited across the the pins.
It may also be open circuited across the pins.

INSULATION RESISTANCE TO EARTH

The resistance of the insulation between the copper conductors and the metal frame of the machine is measured by means of a high voltage tester, or "Megger", which applies a D.C. potential of 500 or 1000 volts across the insulation.



- A = earth or metal frame of machine
- B = Insulation material between conductor and earth
- C = Copper conductors or winding
- P = Path of leakage current through insulation

The leakage current through the insulation gives a direct reading on the meter in megohms, and a normal value should be above 1 megohm.

NOTE

When conducting high voltage test to earth it is advisable to either disconnect or short out any electronic devices, such as voltage control units, diodes etc. Shorting out terminals can be achieved with a piece of fuse wire, which must be removed immediately after the tests are completed.

When megger testing a machine, failure to protect the voltage control unit and diodes could result in permanent damage to one or more of the electronic components.

SECTION 3

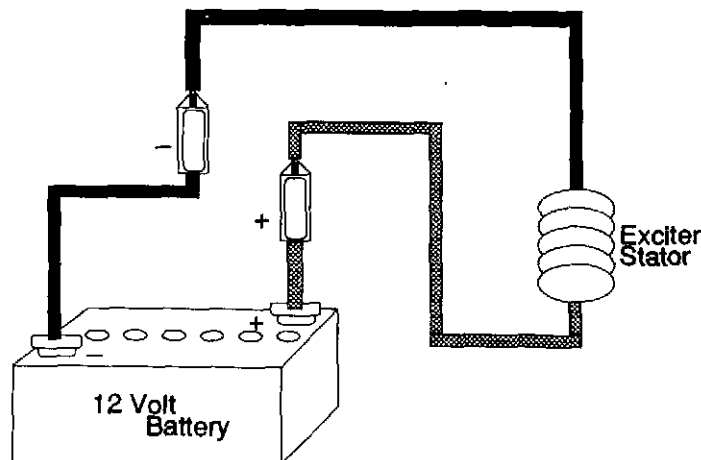
BRUSHLESS 'C' RANGE ALTERNATORS

FAULT FINDING METHOD A FOR ALL 'C' RANGE MACHINES

SEPARATELY EXCITING WITH A BATTERY

NOTE

1. Success with this method depends upon each test being completed before proceeding to the next, unless otherwise stated.
2. Every component in the alternator is checked regardless of the symptoms of the fault, with the exception of the voltage control system which is covered in the Method B test.

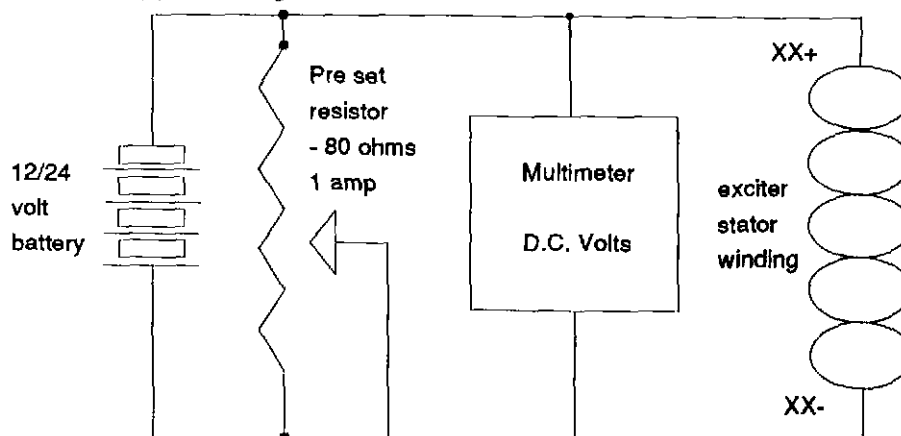


1. Disconnect the exciter stator leads positive and negative, from the voltage control unit terminals X+ and XX- respectively.

NOTE

- Ensure that the correct two leads are located by physically tracing them back to the exciter stator windings, situated in the non drive end bracket.
2. Check the resistance value of the exciter stator across these two leads (approximately 27-30 ohms) with a multimeter.
 3. Check the D.C. voltage required for the machine under test. (see 6 below)
 4. Connect the D.C. battery supply to the exciter leads, positive to X+ or orange, negative to XX- or black.

A variable source can be applied using the circuit as shown:-



5. Run the machine up to full speed. Ensure that the speed is correct for these tests, or the results may be misleading.

6. The following chart gives the approximate D.C. battery Voltages required to produce full voltage output. from the main stator at no load.

It is essential that ALL LOAD is disconnected from the machine, and that the speed is correct.

FRAME SIZE

EXCITATION AT NO-LOAD

HC/SC 144	10-12 VOLTS D.C.
HC/SC2,C20,C30,C40	9-11 VOLTS D.C.
HC/SC3	9-11 VOLTS D.C.
HC/SC4,C434,C534	10-12 VOLTS D.C.
HC/SC5,C45,C50	10-12 VOLTS D.C.
HC/SC6 C634	12-13 VOLTS D.C.
HC/SC7,AC634,AC734	12-13 VOLTS D.C.

7. If the output voltage from the main stator is within 10% of the nominal, or higher than the nominal, and balanced across phases this indicates that the exciter stator and rotor, main rotor, main stator and rotating rectifier are all functioning correctly. Ignore Test 8-13 and proceed directly to Test Number 14. If the output is more than 10% below the nominal, or unbalanced phase to phase, this indicates that a fault exists in one of the above components, and the following tests must be conducted.

8. VOLTAGE UNBALANCED BETWEEN PHASES

The voltages between phases, and each phase to neutral, should be balanced. On a single phase machine the voltage between L1-L4, and L2-L4 or U-N and W-N, must be balanced. IF THE VOLTAGE IS LOWER THAN EXPECTED, BUT PERFECTLY BALANCED PROCEED TO TEST NUMBER 9. If an unbalance of more than 2% is shown, this indicates that a fault exists with the main stator windings. This test should be repeated with all the customers external connections removed to eliminate the possibility of external shorts between the machine and the main isolator. Further tests maybe made on the resistance values of the main stator windings (see MACHINE HANDBOOK) with a KELVIN BRIDGE RESISTANCE METER.

The stator must be rewound if a short circuit is revealed by an unbalanced output. As the short-circuit current represents load the engine, the fault can further be identified by the engine becoming slightly loaded i.e. the engine sound will change.

9. VOLTAGE BALANCED BUT READING LOW

This indicates that a fault exists in either the main rotating rectifier assembly, or one of the excitation windings i.e. the main rotor and/or the exciter stator and rotor. First check that the D.C. separate excitation is not lower than the figure given in Paragraph 6, and that the speed is correct.

TESTING THE ROTATING RECTIFIER ASSEMBLY

10. The diodes on the main rectifier assembly can be checked with a multimeter. The flexible leads connected to each diode should be disconnected at the terminal end, and the forward and reverse resistance checked. The rectifier assembly is split into two plates, the positive and negative, and the main rotor is connected across these plates. Each plates carries 3 diodes, the negative plate carrying negative based diodes, and the positive plate carries the positive based diodes. Care must be taken to ensure that the correct polarity diodes are fitted to each respective plate. When fitting the diodes to the plates they must be tight enough to ensure a good mechanical and electrical contact, but should not be over tightened. The recommended torque tightening is 12 to 15 lbs.ins. (14 to 17Kg.cm).

11. SURGE SUPPRESSOR

This is a protection device which prevents high transients from damaging the main rectifier diodes. It is connected directly across the diode plates on the main rotating rectifier assembly.

The machine will work normally with this device removed.

A faulty surge suppressor will be either open circuit (usually showing burn marks) or short circuit in both directions.

12. TESTING THE MAIN EXCITATION WINDINGS

If after establishing and correcting any fault on the rectifier assembly, the output is still low when separately excited, then the main rotor, exciter stator and exciter rotor winding resistances should be checked as the fault must be in one or more of these windings.

The resistance values are given in the MACHINE HANDBOOK.

The exciter stator resistance is measured across leads X+ and XX-, connected to the voltage control unit and can be checked with a multimeter. the exciter rotor and main rotor resistances can be checked by disconnecting the relevant leads to the main rectifier assembly. The exciter rotor is connected to three studs on the main rectifier assembly, which also carries the diode lead terminals, and must be tested with a KELVIN BRIDGE METER, as the resistance is less than 1 ohm. The main rotor winding is connected across the two rectifier plates, and the respective leads must be disconnected before taking the readings, using the battery resistance test method as described in SECTION 2

13. SENSING SUPPLY FROM MAIN STATOR

Checking the sensing supply from the main stator is the final test which can be carried out while separately exciting the alternator with a battery supply.

The previous tests should have cleared any fault in the windings or rectifier assembly and the correct output obtained from the main stator with the battery. On all the machines, the sensing supply is connected to auxiliary terminals 2 and 3, and voltage control unit terminals 2 and 3. The voltage across these terminals should be between 190 and 240 volts, when the output voltage is approximately correct. If the supply is broken the wiring should be traced back through the machine to the stator to locate the fault.

SECTION 4

SELF EXCITED CONTROL SYSTEM

TEST METHOD B

FAULTY SYMPTOMS AND REMEDIES AT NO LOAD

<u>SYMPTOM</u>	<u>POSSIBLE CAUSE</u>	<u>TEST AND REMEDIES</u>
No voltage (no load)	1)Voltmeter faulty or connected to wrong side of circuit breaker	Check for voltage at alternator terminals with a multimeter.
	2)Loose broken or corroded connections	Check all auxiliary terminals. Check the A.V.R. push on terminals for tightness. Repair/renew where necessary.
	3)Loss of residual voltage (only occurs after severe shock i.e. out of phase paralleling or many years storage prior to use); or after replacement of exciter windings.	Connect a 12 volt D.C. battery supply to A.V.R. terminals X+ and XX- (Polarity MUST be correct) for 2-3 seconds BEFORE running the machine. See test method A SECTION 3.
	4)Field resistor fitted in terminal box open circuit. Note. This is not fitted to machine manufactured after 1977.	Check resistance value (680) ohms). If this resistor is not in the terminal box, ignore these instructions.
	5)Very low insulation resistance to earth (ground) on exciter stator or main stator.	Check the insulation resistance value with a Megger (see section 2). Ensure that neutral is not earthed disconnected A.V.R.
	6)Surge Suppressor on main rotating rectifier short circuit.	Disconnect surge suppressor lead from rectifier fin (see Test Method A Section 3).
	7)Main Rectifier diode/s short circuit.	Check diodes (Section 3 Test Method A) Replace where necessary.
	8)Winding fault. Open circuit or short circuit on any winding in the Machine.	Carry out tests as listed in Test Method A. Check winding resistance values. (see chart in this sections).
	9)Exciter stator polarity reversed by battery tests (test method A).	Re-connect battery to exciter stators ensuring that polarity is correct and re-test.
	10)Fault in A.V.R.	Replace the A.V.R. and re-test machine. Ensure terminals are connected correctly.
	11)Load applied to machine during run-up of engine.	The voltage will not build up until the load is disconnected from the machine. Open circuit breaker and re-test.
	12)Open circuit power supply from main stator to A.V.R. Terminals P1, P2, P3 and P4. Note: Machines built after 1981 will have no lead P4 fitted to the A.V.R.	Separately excite machine as per test methods A, Section 3. Check voltage across P1, P2, P3, P4 at A.V.R. terminals. P1-P2-P3-P4=190-240 Volts. P1-P2-P3-P4 = 50% of above voltage.

Low Voltage
(no-load)

1)Engine speed incorrect

Check speed with tachometer. Adjust governor control to 4% above nominal speed at no load.

2)A.V.R. 'range' control, or external hand trimmer control incorrectly set.

Adjust voltage on 'RANGE' or trimmer. Ensure that No. 1 item is correct. (see above).

3)Voltmeter faulty or sticking.

Check voltage with multi-meter, across machine output terminals.

4)Fault in A.V.R.

Replace A.V.R. and test.

5)Loose broken or corroded connections.

Check the wiring for poor connections. Repair or replace where necessary.

6)Fault on power Supply from main stator.

See item 12, previous test under "No voltage, No load".

High Voltage
(no-load)

1)Engine speed high

Check speed with tachometer or frequency meter. Adjust engine governor if necessary.

2)A.V.R. 'RANGE' control or hand trimmer incorrectly set.

Adjust where necessary. Ensure that the speed is correct first.

3)Sensing supply from stator to A.V.R. terminals 2 and 3 open circuit or low.

Separately excite machine as per Test Method A Section 3 and check sensing supply volts (item 13).

4)Burden resistor (fitted in A.V.R. sensing supply) open circuit.

A fault on the burden resistor will create a high voltage condition. Normal resistance value 215 ohms.

5)A.V.R. fault.

Replace A.V.R. and re-test. Check thyristor in A.V.R (see SECTION 2, resistance tests).

6)Loose, broken or corroded connections.

Check connections on auxiliary terminal board and A.V.R terminals. Repair or replace if necessary.

Voltage unstable
(no load)

1)Engine governor unstable (hunting).

Check for speed instability with a frequency meter. Sometimes this problem will clear when a load is applied to the engine

2)Loose or corroded connections

Intermittent voltage fluctuations, can be created by poor connections. Check auxiliary and A.V.R terminals.

3)Intermittent earth (low insulation resistance).

Megger windings (see section 2 resistance tests).

4)Faulty A.V.R.

Replace A.V.R and re-test. Check A.V.R for broken components or solder joints.

5)Voltmeter faulty/unstable

Panel mounted voltmeter are sensitive to vibration.

Unbalanced voltages Phase to Phase (3 phase machines) or L4 to L1 and L12 (single phase machines) (no-load).

1) Fault on main stator windings

Disconnect all external leads to machine and re-test. Check by separately exciting (Test Method A Section 2). a winding fault will get hot. Check by hand around the stator after running.

FAULT SYMPTOMS AND REMEDIES ON LOAD.

Unbalanced voltages phase to phase (on load only)

1) Single phase loads (phase neutral) unevenly distributed over the three phases.

Check current in each phase with clip-on ammeter. NOTE. The full load rated current must NOT be exceeded on any one phase. Re-distribute load if necessary.

Unstable voltage (on load)

1) Engine governor unstable (hunting)

Check with a frequency meter for speed variations due to governor 'hunting'.

2) Leading Power Factor load created by mains power factor correction equipment.

Isolate the power factor correction capacitors until sufficient motor load has been applied to counteract the leading p.f. (see power factor Section 2).

3) Variation of fluctuation in load current (motor starting etc.).

Check the load on a stable supply i.e. mains, or separately excite the machine. A variable D.C. supply is required for ON-Load separate excitation tests.

4) Thyristor controlled load, causing waveform distortion. (Contact Newage for further information).

Fit a three phase sensing unit (see operation manual for details).

5) Faulty A.V.R.

Replace A.V.R. and re-test on load.

High voltage (on load)

1) Unbalanced load.

Check voltages on other phases. If unbalanced re-distribute loading over three phases.

2) Leading Power Factor load (capacitor banks).

Check excitation volts across X= and XX-. A leading power factor will give an abnormally low D.C. voltage. Remove power factor correction equipment at low loads (see power factors Section 2).

3) Parallel droop current transformers reversed.

Check for reversal (when fitted).

4) Burden resistor incorrectly set across improved regulation transformer (when fitted).

Reduce the amount of resistance across the improved regulation transformer until on-load voltage is correct.

5) Thyristor or rectifier load giving waveform distortion.

Fit three phase sensing unit (see operation manual for details).

Poor Voltage Regulation (more than 2.5%) (no load)

1) Large speed droop on engine.

Check that engine speed droop from no load to full load is no greater than 4%.

2) Unbalanced load.

Check voltages on all phases and current. If unbalanced redistribute load more evenly across the phases.

	3) Parallel droop equipment fitted.	Too much parallel droop in circuit will give poor regulation. For single running machines this can be improved by fitting shorting switch across the droop equipment. (burden resistor).
	4) Voltage droop between machine and load, due to volts drop on long cable run or under rated cable diameter.	Check the voltage at both ends of the cable run. Large differences in voltages indicate a large volts drop along the cable. A larger diameter cable is required in severe cases.
	5) Improved regulation equipment reversed (when fitted).	Reverse the secondary leads on the transformer, and re-test the machine.
	6) Fault on main rectifier or excitation windings.	Check the no-load excitation volts across A.V.R. X+ and XX-. Compare with the D. c. voltages as listed in Test Method A Section 3. If higher than listed, proceed with Test Method A.
Poor response to load surges.	1) Engine fault of governor faulty.	Check performance of engine with tachometer or frequency meter during load surges.
	2) Parallel droop resistance incorrectly set.	See parallel section 9. Too much parallel droop will create large voltage dips with motor starting etc..
	3) Load surges exceed 2.4 times the full load current.	Check load surges with a clip on ammeter. Voltage dip may be excessive if the overload exceeds 2.5 times full load.
	4) Large volts drop on cable run between machine and load.	See previous section on poor regulation item 4. This also applies to high current surges (motor starting etc.).
	5) Motor contractors dropping out due to voltage dip.	All symptoms and remedies in this section may apply to this problem.
	6) Faulty A.V.R.	Replace and re-test on load.
	7) Fault on windings or rotating rectifier.	Complete Test Method A Section 3. A fault in this area will show an an excitation voltage across X+ and XX-, much higher than listed in Section 3.
Low voltage (on load)	1) Engine speed droop greater than 4%.	Check speed no load and full load. Engine governing is unsuitable/fault if greater than 4% droop.
	2) Fault on winding or rotating diodes.	Complete all tests as listed in Test Method A Section 3.
	3) A.V.R. faulty	Replace and re-test.
	4) Fault on power supply from main stator to A.V.R.	See item 12 on previous text under "No Voltage, No Load".

SECTION 5

SEPARATELY EXCITED

(WITH PERMANENT MAGNET GENERATOR EXCITER)

TEST METHOD B

FAULT SYMPTOMS AND REMEDIES AT NO LOAD

SYMPTOM

No voltage (no load)

POSSIBLE CAUSE

1) Fault on permanent magnet generator stator or rotor.

2) Earth on permanent magnet stator.

3) Voltmeter connected wrong side of circuit breaker or not working.

4) Loose, broken or corroded connections.

5) Protection circuit tripped, collapsing output voltage.

6) Surge suppressor on main rectifier short circuit.

7) Diode short circuit on main rotating rectifier assembly.

8) Open circuit or short circuit in main exciter windings.

9) Faulty Voltage Control Unit/Protection circuit.

TEST AND REMEDIES

Disconnect the P.M. generator leads from A.V.R terminals P2, P3, P4. With a multimeter check the output volts across these leads with the set running at correct speed, 50Hz, 1500rpm. Across P2, P3 and P4 the voltage should be approximately 160 volts A.C. For 60Hz, 1800rpm, add 20% to the above voltages.

Disconnect leads P2, P3, P4 and "megger" to earth (see Section 2)

Check for voltage at alternator output terminals with a multimeter.

Check and repair/renew where necessary.

(a) Shut down the set, and run up again. If the voltage builds up normally then collapses again the protection unit has operated. (b) With the machine at full voltage (no-load) check the excitation voltage across A.V.R X+ and XX. If greater than 12 volts D.C. carry out Test Method A. Ensure speed and output voltage is correct for this test.

Disconnect surge suppressor lead from rectifier (see item 2 Test Method A). If voltage builds up when machine is run, replace the suppressor.

Check diode (see Section 3 Test Method A) and Section 2. Replace where necessary.

Remove external leads from machine and separately excite as per Test Method A, Section 3. Complete all tests as suggested in 'A' Method.

Change A.V.R and test by running the machine.

Low Voltage (no load)

- | | |
|---|--|
| 1) Engine speed incorrect | Check and adjust governor if necessary |
| 2) A.V.R 'Range' control control incorrectly set. | Adjust control CLOCKWISE to increase voltage. If remote hand trimmer fitted, adjust in conjunction with trimmer. |
| 3) Hand trimmer faulty. (if fitted). | Check resistance of trimmer (5K ohms across outer pins) |
| 4) Fault in A.V.R component. | Replace A.V.R and test by running machine. |
| 5) Power diodes in A.V.R short circuit | Open A.V.R box, and check the five stud-mounted diodes (see Section 2). |

High Voltage (no load)

- | | |
|---|--|
| 1) Engine speed to high. | Check speed and correct if necessary. (note no load engine speed should be approx 4% above nominal, unless a special 0.5% speed droop governor is fitted). |
| 2) A.V.R Range control or remote trimmer incorrectly set. | Check and adjust if necessary. |
| 3) Main thyristor short circuit | Open A.V.R and check main thyristor. (see Section 2). |
| 4) Burden resistor open circuit. (When fitted). | Disconnect burden resistor (fitted external to machine) and check resistance (215).. Also check tapping bands and connections for tightness. |
| 5) Sensing supply open circuit | Separately excite machine (see Test Method A Section 3) and check sensing supply volts (item 13) |
| 6) Low sensing supply from main stator. | Check as item 5 |

Unstable Voltage (no load)

- | | |
|--|---|
| 1) Engine speed 'hunting' (unstable) | Check with a frequency meter. If the frequency is fluctuating the engine governor must be checked. |
| 2) Permanent magnet stator positioned incorrectly. | The position of the stator housing is important to the stability and response of the A.V.R. Following tests in this section explain the setting up procedure. |
| 3) Fault in A.V.R | Replace and test by running the machine. |
| 4) Loose or corroded connections | Check push on terminals on A.V.R. Check auxiliary terminals for loose connections. Repair or replace as necessary. |
| 5) Intermittent earth on machine | Megger all windings to earth (see Section 2). |

Unbalance Voltage Phase to phase (no load) 1) Fault on main stator winding.

Disconnect external leads and check again. Check winding resistance value. Set Test Method A (item 8). A winding fault will get hot. Check by hand around stator winding for "Hot Spot".

FAULT SYMPTOMS AND REMEDIES ON LOAD.

Unbalanced Stator Voltages (on load)

1) Single phase load current unevenly distributed over the three phases.

Check with clip on ammeter the current in each phase. NOTE: The full load rated current must not be exceeded on any one phase. Re-distribute load if necessary.

Unstable Voltage (on load)

1) Engine governing unstable (hunting)

Check for "hunting" with a frequency meter.

2) Leading power factor load created by mains power factor correction capacitors.

Isolate the power factor correction equipment until sufficient motor load has been applied to counteract the leading power factor. (See Power Factors Section 2).

3) Permanent magnet stator positioned incorrectly.

See following information in this section for details.

4) Thyristor or rectifier loads causing waveform distortion.

Fit a three phase sensing unit (see Operation manual for details). Contact Newage International for further information.

5) Fault in A.V.R

Replace and test by running machine on load

6) Fluctuating load current or continuous variation in load demand.

Check load current on stable supply i.e. separately excite machine or test load on mains supply. a variable D.C. supply is required for onload separate excitation tests. (See Section 3). Stable D.C. should identify cause of instability.

voltage Regulation (on-load)

1) Large engine speed droop.

Check that the speed droop from no load to full load is no greater than 4%.

2) Excess amount of parallel droop resistance in circuit (when fitted).

Check the burden resistor setting across the parallel droop transformer. NOTE: of 2.5%. Regulation is required on a single running machine fitted with parallel droop equipment, a shorting switch must be fitted across the parallel droop transformer.

3) Unbalance load

Check voltage across the phase. If unbalanced re-distribute the load more evenly across the phases.

4) Fault on A.V.R

Replace unit and retest machine.

5) Voltage drop between alternator and load, due to long run of cable, or under-rated cable diameter.

Check the voltage on load at both ends of cable. Large differences in voltage indicates a large volts drop in supply cable.

Poor Response to Load Surges.	6) Fault on main rectifier or excitation winding.	Check the no load excitation voltage across A.V.R x+ and XX-. If higher than 12 volts D.C. the machine must be tested as per Test Method A (Section 3).
	7) Permanent Magnet stator position incorrect.	See following test for alignment of the P.M. stator.
	1) Engine governor sticking or slow to respond	Check performance of engine during application of load.
	2) Parallel droop resistance set incorrectly (When fitted).	Check the resistance value across the droop transformer.. an excessive will produce large voltage dips on motor starting etc..
	3) Load current surges exceed 2.5% times full load of the machine.	Check surges with clip on ammeter. Check with Newage for advice on starting characteristics.
	4) Large volts drop on cable run between alternator and load, during starting surges.	Check the voltage drop during the starting, at alternator and load end of cable.
	5) Incorrect position of permanent magnet stator.	The position of the P.M. Stator affects the response performance of the A.V.R. See following text for details.
Voltage collapses (on load)	6) Motor contactors dropping out due to voltage dip on starting	Check as per items 1 to 6
	7) Fault in A.V.R	Replace and test on load
	8) Fault on windings or rotating rectifier.	Test by completing the Test Method A Section 3
	1) Protection circuit operated due to overload on excitation system	(a) Check that the load current does not exceed full rating of machine. (b) check speed and ensure this is correct at full load (c) Check output voltage and ensure it does not exceed the rated voltage
	2) Protection circuit operated due to fault on windings or diodes	Carry out full tests as per Test Method A Section 3
High Voltage (On load)	3) Malfunction of protection circuit	Change A.V.R and test on load
	4) Severe overload or short circuit on load	Check load current with clip on ammeter. The permanent magnet will sustain a high short circuit current if a fault exists.
	1) Unbalanced load	Check voltage on other phases. If unbalanced redistribute loading over the three phases.
	2) Leading Power Factor Load	Check excitation volts. A leading power factor will give abnormally low D. C. voltage across X+ and XX- Disconnect capacitor banks (see Power Factors, Section 2)

3) Burden resistor incorrectly set across improved Regulation Equipment (when fitted)

Reduce the amount of resistance across the improved regulation transformer, until on-load voltage is correct.

4) Parallel droop transformer reversed. (when fitted)

Check for reverse droop equipment P1/P2 or S1/S2.

5) Thyristor or rectifier load creating waveform distortion.

Fit a three phase sensing unit (see Operation Manual for details). NOTE: Special VCU required.

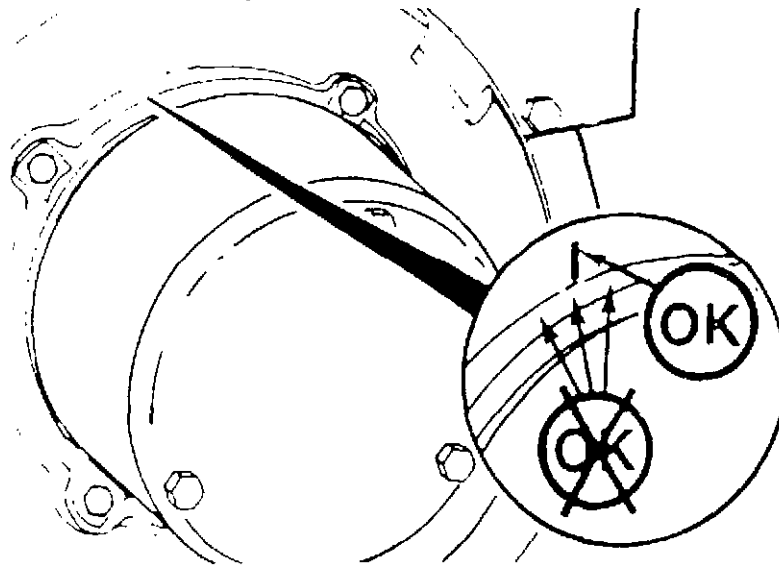
NOTE MACHINES MANUFACTURED BEFORE 1989

SETTING UP PROCEDURE FOR THE PERMANENT MAGNET GENERATOR

The Permanent Magnet Generator is fitted to all machines which have Series II or Series III control systems. The magnetic rotor is fitted to the non-drive end of the main shaft, and the stator is located in a spigot on the non-drive end bracket, being held in position by four washers.

The position of the Permanent Magnet Stator is set during the final electrical test prior to despatch, and a mark indicating this position is made on the stator housing and non drive end bracket at approximately the twelve o'clock position. This necessary to obtain the best performance from the voltage control system, and is an essential part of the setting up procedure.

Should there be the necessity to dismantle the machine, the Permanent Magnet Assembly will have to be removed, and for this reason the following points should be observed.



When re-fitting the Permanent Magnet Assembly, providing the units are NOT replaced with new components, the only essential requirement is that the stator housing positioning mark is adjacent to the mark made on the non-drive end bracket. The rotor has a dowel pin which fits into a locating hole on the main shaft and it is therefore not possible to get this in the wrong position if correctly fitted.

However, if during the lifetime of the machine, it is necessary, to replace or rewind any of the main components or windings within the machine, it will be necessary to re-adjust the Permanent Magnet Stator position. Similarly, it should be noted that the reconnection of the main stator windings (6 and 12 wire machines) from Series and Parallel Star or Double Delta, or visa versa, must also be followed by re-adjustment of the P.M. Stator as follows:-

1. Fit the complete assembly and tighten all bolts ready for normal running.
2. Connect a voltmeter across the main output terminals, such that the reading can be observed while adjusting the Permanent Magnet position.

3. Run the machine to full speed and while firmly holding the stator housing in position, loosen the clamp washer bolts approximately one turn, until slight movement is allowed.

WARNING:- Under no circumstances should the Permanent Magnet Stator housing be allowed to move out of its spigot, even slightly, as there is a risk that the stator will foul on the rotor. If there is any doubt, two men should be employed in loosening the bolts and holding the housing in position.

4. Rotate the whole stator housing slightly clockwise and anticlockwise while observing the output voltage. At the LOWEST voltage level, Mark the position on the P.M. Stator housing and the end bracket.

NOTE:- The maximum movement clockwise or anticlockwise is approximately 3"(8cms)

5. Rotate the P.M. Stator housing clockwise until the machine output voltage is at its HIGHEST level. Mark this position on end bracket.

NOTE:- The voltage variation will be approximately 5% from maximum to minimum.

6. Rotate the P.M. Stator housing ANTICLOCKWISE to exactly half way between the two positions, and tighten the clamp washers.

7. The P.M. Stator is now positioned correctly for ideal voltage response and regulation. The position should be marked permanently with a punch or chisel on the end bracket and P.M. Stator housing.

PARALLEL OPERATION 'C' RANGE A C GENERATORS

(1) INTRODUCTION AND THEORY

No one aspect of the a.c. generator set operation causes more misunderstanding than the parallel operation of two or more a.c. generators.

This report will explain the reasons for paralleling, the method by which it is carried out, the setting up procedures and possible problems that may arise.

Parallel Operation may be necessary for the following reasons:-

- (1) To increase the capacity of an existing system
- (2) Size and weight may preclude the use of one large unit.
- (3) Allows non-interruption of the supply when servicing is required.

In order to parallel a.c. generators satisfactorily, certain basic conditions have to be met. These are as follows:-

- (1) All systems must have the same voltage
- (2) All systems must have the same phase rotation
- (3) All systems must have the same frequency
- (4) All systems must have the same angular phase relationship
- (5) Systems must share the load with respect to their ratings.

A minimum amount of instrumentation is required to ensure the above information is satisfactorily monitored, comprising an ammeter, a wattmeter and a reverse power relay. No voltmeter is specified for each system because it is preferred to use one voltmeter on the distribution or synchronising panel with a selector switch for each system. This eliminates any possible meter inaccuracies.

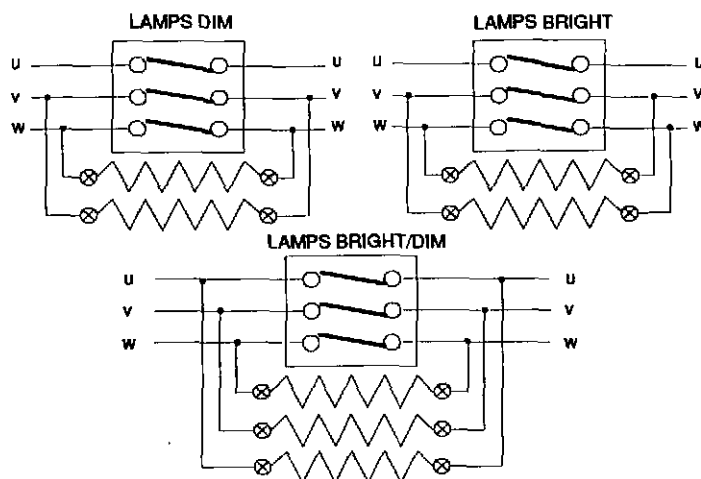
A reverse power relay, although contributing a larger proportion of the instrumentation cost, is essential as any engine shut down, from low oil pressure, over temperature etc. will result in other systems motoring the failed set with consequent overload to the remaining systems.

Only one frequency meter is required with the facility of being switched to the busbar of the incoming system.

A synchroscope and/or lights, is required to detect the angular phase displacement. If lights are used three different connections are possible. For paralleling with the lights dim, they must be connected across like phases or like lines (single phase), i.e. U-U, V-V or L1-L1. For paralleling with lights bright they should be connected across unlike phases, i.e. U-V etc..

If a three lamp system is used with the lamps connected across U-W, V-V and W-U the lamps will 'rotate' and give an indication which machine is running fast. Synchronism is reached with two lamps bright and one dark and in some respects this connection gives a closer visual indication of the point of synchronism. Note the lamps should be rated for at least twice the machine voltage or it will be necessary to connect two or three in series. A more preferred method is a resistor/lamp combination.

The following diagrams illustrate the connections:



Note: If the neutral is solidly linked, then only one set of lamp/resistors is required because the return path is through the neutral link. This, of course, only applies to the lamps dim and lamps bright connection, and not on the three lamp connection.

LOAD SHARING

The most important aspect of parallel operation is load sharing. The total load, comprising a kW or active component and a kVAR or reactive component, must be shared by the systems with respect to their normal ratings.

The kW component is adjusted by purely mechanical means and requires relatively fine speed control of the prime mover. It is advisable to fit a limited range governor to avoid 'misuse' of the speed control.

The kVAR component is a function of the a.c. generator excitation. When machines are in parallel, the magnitude of the field excitation cannot directly influence the output voltage. It does however, adjust the internal power factor at which a particular machine operates. For instance, an over-excited a.c. generator will draw leading current. If a difference in excitation exists, then circulating currents will flow, limited only by the internal machine reactance. This current will appear only by the internal machine reactance. This current will appear as a zero p.f. leading or lagging current depending on the machine excitation and will either subtract or add to the total current that each machine supplies. Reactive current, either leading or lagging is by virtue of the 90 degree phase displacement quite commonly described as being quadrature.

Means must, therefore be provided to sense this reactive current and limit it to an acceptable level. Hence a quadrature droop kit. This comprises a current transformer (CT) and a burden resistor.

2. GENERAL NOTES ON SETTING UP PROCEDURE

Stable parallel operation and accurate load sharing between no load and full load can only be obtained when the initial voltage settings and droop kits are correctly set up. It is also most important the the governor characteristics are similar otherwise incorrect kW load sharing can result when wither increasing or reducing load.

To check the no load voltage settings, run each machine singly at the normal no load frequency, i.e. 51.5Hz for 50Hz operation or 62Hz for 60Hz operation. The rated voltages should now be set to within 1% of each other. In the case of machines fitted with hand trimmers, this is a simple operation..

(a) Machines with series 2, 3 or 4 excitation system.

These machines have a 'RANGE' voltage adjustment on the A.V.R and may also be fitted with a remote hand trimmer. Voltage adjustments is therefore a straight forward operation.

(b) Machines with series 1 excitation system (Frames C/MC20-50).

The majority of these machines were fitted with a frequency sensing unit (F.S.U.) with voltage adjustment being achieved by the selection of the F.S.U. tappings.

These are brought out to a terminal block and numbered between one and twelve. The machine will operate at maximum volts if tapping one and twelve are selected, and at minimum voltage when tappings two and three are used. It is a matter of selecting the correct taps by test. This operation, of course, is normally carried out prior to Works' despatch, but changes may be necessary in the field when different voltages are required.

The actual tappings that are used to give the desired voltage are not of importance. For instance, two identical machines may use different tappings to give similar voltages. It may be necessary to make some slight adjustment to the 'gain' control on the voltage control unit. This control although fitted to adjust the stability and response of the circuit, does affect the no load voltage and in consequence enables a more accurate no load voltage setting to be obtained than with the F.S.U. tappings alone.

Extreme caution should be exercised when changing the 'gain' control and in any case it should only be turned anti-clockwise on the machine generating the highest voltage. UNDER NO CIRCUMSTANCES should it be turned clockwise as instability problems may result.

QUADRATURE DROOP EQUIPMENT

The most important aspect of initial setting up procedure concerns the droop kit. Most of the troubles allied to poor parallel operation originate from the droop kits. They are either incorrectly adjusted for the level of voltage droop or are incorrectly connected such that a rising voltage characteristic is obtained. If a machine is specified

for parallel operation at the time of ordering, then the droop kit supplied will have been set up on test. So long as the terminal markings and connections are followed, no problem should result.

NOTE: Reversal of the transformer or reversal of the secondary connections to the transformer will result in a rising voltage characteristic which is completely unstable during parallel operation.

Where machines have to be modified to incorporate a droop kit at a later date, ensuring a drooping voltage characteristic appears to be of the greatest difficulty. As previously stated, the droop kit is correctly adjusted when the terminal voltage droops 5% with zero p.f. or reactive current equal to the full load current being supplied.

To obtain such a reactive current, loads such as unloaded motors or welders etc. are required. The majority of set builders do not possess any such equipment and rely on heaters and water barrels for their load. This is, of course, a resistive load and of little apparent use in checking for voltage droop.

However if slight modifications are made to the standard droop circuit, and effective duplication of zero power factor reactive load can be obtained using unity power factor resistive load.

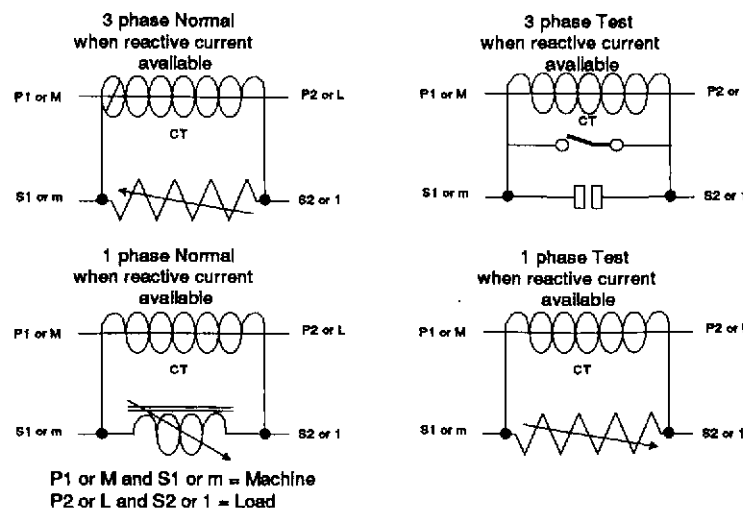
This entails replacing the burden resistor with an electrolytic capacitor in the case of 3 phase machines, and replacing the choke with a resistor when using 1 phase machines.

For 3 phase machines use 50uf 50V capacitor.

For 1 phase machines use 50 ohms 30W resistor.

The following diagrams illustrate the connections:-

When using the 3 phase test, care should be taken to ensure that the capacitor is only connected for a few seconds at a time and it is advisable to connect a switch across the capacitor to enable a rapid disconnection to be made.



The correct polarity of the transformer is observed when the terminal voltage droops. If the voltage rises on the application of load, leads S2 or 1 and S1 or m should be reversed either at the CT secondary or at the resistor/capacitor/choke.

The above test give a check on the polarity of the droop kits. To check for the correct level of droop is more difficult, but the test capacitors and resistors should give a close enough indication of the amount of resistance required.

For instance, a 50uf capacitor has an impedance of about 60 ohms at 50/60Hz. If the voltage droops off about 5% with this capacitor connected in circuit, the burden resistor should also be adjusted such that 60 ohms is in circuit.

TESTING THE PARALLEL DROOP CIRCUIT FOR REVERSAL

1. Adjust the burden resistor to put the maximum amount of resistance across the parallel droop transformer. Make a note of the previous setting prior to this adjustment.

2. Run the machine singly at full rated speed, and apply as much inductive load (i.e. motors transformers etc.) as can be obtained.
3. Make a note of the output voltage from the machine terminals.
4. With a shorting link or insulated screwdriver, short circuit the resistance across the parallel droop transformer, and observe the output voltage from the machine.
5. If the voltage has risen slightly, this indicates that the droop circuit is functioning correctly.
6. If the voltage has drooped slightly, the droop transformer is reversed, and the connections of its two output leads should be changed over.
7. After completion of this test, re-set the burden resistor to its original correct setting.

If the voltage droop more than 5% then less resistance is required in the burden resistor. Conversely, a lower droop requires more resistance. As a further guide, the following values of resistance have been found to give satisfactory results.

C20	50 ohms	SC2	50 ohms	SC6 60 ohms
C30	40 ohms	SC3	50 ohms	SC7 60 ohms
C40	40 ohms	SC4	60 ohms	
C45	30 ohms	SC5	60 ohms	
C50	30 ohms			

IMPROVED VOLTAGE REGULATION EQUIPMENT

Should load sharing in parallel prove to be difficult it may be necessary to reduce the improved regulation resistance setting or short circuit the equipment completely.

When paralleling similar machines the setting on this equipment should be approximately equal on all machines.

SINGLE RUNNING OPERATION OF MACHINES WITH PARALLEL DROOP

The voltage is required to droop at least 2.5% for satisfactory load sharing in parallel. If better regulation is required for single machine operation a shorting switch must be fitted across the parallel droop equipment.

This switch should be mounted on the instrument panel, clearly marked 'PARALLEL RUNNING; in the open circuit position.

STEP BY STEP SETTING UP PROCEDURE

The points below are meant as a general guide only. If any doubts exists as to the reason for various tests, further reference should be made to the preceeding notes. All machines must obviously be correctly wired in accordance with the appropriate connection and wiring diagrams.

- (a) Run No. 1 a.c. generator on no load at rated speed. Check a.c. voltage and adjust where necessary.
- (b) Check phase rotation of No. 1 generator.
- (c) Run No. 2 a.c. generator and proceed as items a and b
- (d) With Nos. 1 and 2 generators running on no load, switch in synchroscope or lights.
- (e) Adjust speed until synchroscope rotates very slowly or lights slowly brighten and dim.
- (f) Check finally that voltages are equal or within 1% of each other. Adjust as required.
- (g) Close breaker at synchronism; observe ammeters for circulating current. if in excess of 5% recheck no load voltage settings and droop kits for polarity (reversal).
- (h) Increase load until full load appears on each generator when in parallel. Some adjustment to one engine governor may be required to ensure balanced kW meter readings.

- (i) Check the ammeter readings with the kW meters equal. They should be within 5% of each other.
- (j) If the ammeter readings are outside 5%, (first check that the meters are all accurate) the machine with the highest current is over excited and therefore requires more droop to compensate. Increase the droop resistance, or reduce the improved regulation resistance (when fitted).
- (k) With full load on each generator reduce the external in 20% increments. At each loading, observe kW meter and ammeter readings down to 20% full load. any variation of either instrument beyond 5% of each other requires correction.
- (l) Unequal kW sharing implies a faulty prime mover, most likely the governor.
- (m) Unequal ammeter readings at the full load end of the range imply incorrect levels of droop.
- (n) Unequal ammeter readings approaching the no load condition imply incorrect voltage settings.

4. WORKING PROCEDURE

The most likely procedure that occurs in practice concerns the paralleling of additional machines to already loaded sets. For instance, if a set is supplying a load equal to 75% of its output and further load is anticipated, the resident engineer may decide to spread this load over two sets. A procedure somewhat on the lines of the following is required.

The incoming set is started and run at no load frequency. The synchroscope/light switch is closed connecting the incoming machine and the busbar via the synchroscope or lights. As the incoming machine is fast, the synchroscope will rotate in the fast direction or the lights will brighten and dim at the rate dependent of the frequency difference.

The speed of the incoming machine should be reduced by actuating the motorised governor in the slow direction.

When the frequencies are nearly equal, the speed of rotation of the synchroscope or the changes in brilliance of the lights will be slow enough to enable the set contactor to be closed when the voltages are in synchronism. This will be at twelve o'clock position on the synchroscope or with lights bright or dim dependent on which connection is used.

In order that the incoming machine may now take its share of the load, the governor control should be held in the speed raise position until the desired load is indicated by the kW meter and ammeter. Conversely, if too much load is applied it can be reduced by holding the governor control in the speed lower position. It is most important that the total load be shared in respect of their normal ratings and the meter readings should be compared with the name plate data. In any event, unequal load sharing requires correction to avoid mechanical problems which occur when diesel engines are run light for any considerable time.

It is important to differentiate between unbalanced loading caused simply by the operator failing to spread the load equally over the two sets, and by circulating currents unbalancing the ammeter readings.

For example: consider 2-100kVA generators in parallel with no circulating currents supplying 150kVA 0.8 p.f.

With the load distributed equally, meter readings would appear as follows:

	Volts	AMP	kW	kVA	p.f.
Machine No. 1	415	104	60	75	0.8
Machine No. 2	415	104	60	75	0.8

If the load were distributed unequally, again no circulating currents, the following figures could appear:

	VOLTS	AMP	kW	kVA	p.f.
Machine No. 1	415	139	80	100	0.8
Machine No. 2	415	69	40	50	0.8

If now the same unequally distributed load is being supplied, but circulating currents are present, meter readings something on the lines of the following could be observed.

	VOLTS	AMP	kW	kVA	p.f.
Machine No. 1	415	185	80	133	0.6 lag.
Machine No. 2	415	60	40	43	0.93 leading.

Machines No. 1 is now supplying 133kVa at 0.6p.f considerably in excess of its normal rating. Continued operation under this loading would cause the overload protection circuit to trip or the main stator and the rotor to fail. Machine No. 2 is operating so under-excited that it is operating at a leading power factor and at much reduced kVA.

This will in no way damage No. 2 generator, but in itself implies that No. 1 generator is very heavily over-loaded. a leading power factor condition is particularly difficult to detect except when individual power factor meters are fitted. The normal instrumentation of ammeter voltmeter and kW meter cannot indicate such a load condition.

5. DIFFICULTIES:

Some paralleling problems that can occur are detailed below. Probable causes are also shown.

(a) Oscillating kW meter, ammeter and voltmeter.

Cause: Engine governing, replace by known serviceable unit.

(b) Unbalanced ammeter readings. kW meters balanced and stable.

Cause: Circulating current through incorrect voltage settings, droop kit connections reversed or insufficient droop.

(c) Unbalanced ammeter readings on no load or rapidly rising currents as soon as contactor is closed.

Cause: Incorrect voltage settings or droop kit connections reversed.

(d) Unbalanced kW and ammeter readings as load increased or decreased.

Cause: Dissimilar governor speed regulation.

(e) Unbalanced ammeter readings as load increased. kW meters balanced.

Cause: Droop circuit setting not identical or one droop kit reversed.

Apart from the above problems, certain peculiarities may exist which are in no way detrimental to the operation of the sets. They may, however, confuse the operator into thinking a fault exists.

The most common query results from voltage oscillation during the initial paralleling procedure.

When an additional set is being connected to the busbars with the synchroscope/lights switch in the on position, a point may be reached where the incoming machine voltage starts to fluctuate. This only occurs when the frequency difference is at its greatest. As the frequencies approach each other, no further instability is noticed. This is not, however, a function of the stability circuit within the AVR., but relates to 'pickup' problems associated with the switchboard wiring.

6 NEUTRAL INTERCONNECTION

It should be noted that paralleling of all system neutrals can under certain circumstances lead to over heating or possible stator burn outs.

This is particularly evident when machines of dissimilar type/manufacture are paralleled. Differences in generated waveshape may cause large harmonic circulating currents through the neutrals.

The neutrals of dissimilar machines must, therefore, never be connected.

On the other hand, neutrals of like machines may be connected.

7 PARALLELING WITH THE MAINS

The procedure followed in this instance is no different from that used when paralleling two a.c. generator sets. It is however, advisable to increase the droop resistance to give 10% droop as opposed to the usual 5%. This is the only modification required to ensure stable operation in conjunction with the public supply.

PARALLEL OPERATION FAULT FINDING CHART

SYMPTOM

POSSIBLE CAUSE

REMEDY

1. Circuit breaker will not close when attempting to parallel machines.

(a) Circuit breaker fitted with protection trip which prevents out of phase paralleling.

(b) Phase rotation of one machine is different to the other.

(c) Voltage difference between the machines is too great (circuit breaker fitted with voltage level trip).

(a) Ensure that the synchroscope indicates that machines are IN-PHASE or at the eleven o'clock position when rotating in a clockwise direction. Ensure that the speed difference between the sets is small enough to prevent rapid rotation of the synchroscope or rapid fluctuations of the lights before closing circuit breaker.

(b) Check the phase rotation of each machine when connected individually to the bus-bar. NO ATTEMPT TO PARALLEL must be made until this is correct. Reverse two phases if incorrect.

(c) If one machine is loaded, there should be more than 2.5% voltage difference between machines. When paralleling NO-LOAD, the voltages should be EXACTLY EQUAL.

2. Difficulty in maintaining a stable IN-PHASE condition prior to synchronising.

(a) Governor drift on one or more of the engines.

(b) Load variation on the bus-bars causing speed/voltage dip on the loaded machines/machine.

(a) Let engines stabilise (warm up) before paralleling. If speed is still drifting check governors and engine condition.

(b) Remove any rapidly varying load. Check that there is no likelihood of a motor or automatic load cutting in when paralleling is attempted. DO NOT attempt to parallel if the above condition exists.

3. Voltage and Frequency fluctuating when in parallel.

Cyclic irregularity between the engines.

(a) Increase the NO-LOAD/FULL-LOAD speed droop of the engine if less than 4%. Check for "sticky" governors on new sets.

4. Voltage fluctuating in sequence with the synchroscope revolutions, prior to paralleling.

This symptom is the result of line pick-up between machines in the switchboard circuits, when a hand trimmer, earth leakage detection or paralleling equipment is fitted external to the machines.

The fluctuation will cease when the machines are in synchronism, and will disappear completely when the circuit breaker is closed. If really bad, then the external auxiliary wiring to the alternator must be repositioned away from the main cables, or screened.

5. Voltage and current rise rapidly as circuit breaker is closed.

Parallel droop equipment reversed on one of the machines.

Check the droop equipment for reversal as suggested in previous tests.

SYMPTOM**POSSIBLE CAUSE****REMEDY**

6. Circulating current on one or both machines at no load which is quite small.

(a) Voltage difference (excitation level) between the machines.

(a) Test each machine individually for voltage with the circuit breakers open. They should be exactly equal.

(b) Parallel droop equipment reversed on both machines.

(b) Check the droop equipment for reversal as suggested in previous test.

(c) Incorrect setting of parallel droop equipment.

(c) Increase or adjust amount of droop resistance in circuit.

7. Kilowatt meters giving unbalanced readings, in parallel ON-LOAD.

Engines not sharing the power equally.

Adjust the speed of one engine to equalise the kilowatt sharing.

8. Ammeter giving unbalanced or unequal readings after adjustment has equalised the kilowatt sharing.

(a) Voltage difference (excitation levels) between the machines.

(a) Test the machines individually for exact voltage at NO-LOAD.

(b) Parallel droop equipment incorrectly set.

(b) Adjust as stated in previous test.

(c) Improved regulation equipment affecting the load sharing. (when fitted).

(c) Short out the improved regulation equipment and test again. Re-adjust if this is causing the problem.

9. Kilowatt readings becoming unbalanced as load is increased or decreased.

Engine governors are incompatible, giving power sharing variations at different levels.

The engine governor springs must be adjusted to give NO-LOAD/FULL LOAD speed characteristics. Check for sticking governors on new or repainted engines.

10. Ammeters readings becoming unbalanced as load is increased or decreased, with the kilowatts.

(a) Difference in parallel droop level settings.

(a & b) Load the machines individually with resistive load at approximately four different load levels. Take readings at each level and compare them with the other machine. Adjust the improved regulation equipment (if fitted) to equalise the characteristics. Repeat the above with as much inductive load as possible i.e. motors, transformers etc.. Take voltage readings at each level, and adjust the parallel droop equipment, to equalise the characteristics.

(b) Difference in improved regulation settings.

These settings are the major contributing factors to the load/voltage characteristics of the machine, and therefore must be set to give equal characteristics to the machines with which it is to be paralleled.

11. Voltage regulation poor as a single running machine.

Excess amount of parallel droop in circuit.

For normal regulation a shorting switch should be fitted across the parallel droop transformer. This should be marked "Single/Parallel" operation. Reducing the droop setting too much could result in circulating current in parallel, and should be avoided if possible.