



Guide to Synchronising and Load Sharing

PART 1 – Usage of DSE Load Share Controllers in synchronisation / load sharing systems.

Document Number 057-045 Issue 11

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Deep Sea Electronics Guide to Synchronising and Load Sharing

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1 BIBLIOGRAPHY

1. Diesel generator handbook. L.L.J.Mahon. ISBN 0-7506-1147-2
2. On-Site Power Generation. EGSA Education Committee. ISBN 0-9625949-3-8

TABLE OF CONTENTS

Section	Page
1 BIBLIOGRAPHY	2
2 INTRODUCTION	5
3 STEP BY STEP GUIDE	5
3.1 CLARIFICATION OF NOTATION AND TERMINOLOGY USED WITHIN THIS PUBLICATION.....	6
4 GENERATOR USES.....	7
4.1 STANDBY GENERATORS.....	7
4.1.1 TRANSFER SWITCH.....	7
4.1.2 NO BREAK TRANSFER.....	7
4.2 CONTINUOUS PARALLEL OPERATION.....	8
4.3 BASE LOAD WITH DSE '20 CONTROLLER.....	8
4.3.1 TRUE PEAK LOPPING AND IMPORT/EXPORT CONTROL	9
4.4 MULTIPLE GENERATORS	10
4.4.1 MUTIPLE SET PRIME POWER	10
4.4.2 MULTIPLE SETS PROVIDING STANDBY TO THE MAINS SUPPLY	11
4.4.3 LOAD-SWITCHING USING DSE333 ATS (BREAK TRANSFER)	11
4.4.4 MULTIPLE SETS (STANDBY) – NO BREAK TRANSFER	12
4.4.5 MULTIPLE MAINS SUPPLIES.....	12
5 SYNCHRONISING AND LOAD SHARING SOLUTIONS	13
5.1 SINGLE SETS	13
5.1.1 SINGLE SET NO BREAK RETURN WITH MAINS	13
5.1.2 SINGLE SET FIXED EXPORT.....	13
5.2 MULTIPLE SETS	14
5.2.1 MULTIPLE SET PRIME POWER	14
5.2.2 MULTIPLE SET STANDBY TO MAINS SUPPLY (BREAK RETURN)	15
5.2.3 MULTIPLE SET STANDBY TO MAINS SUPPLY (NO BREAK RETURN)	16
5.2.4 MULTIPLE MAINS SUPPLIES.....	17
5.2.5 SINGLE SET STANDBY TO MULTIPLE MAINS SUPPLY (NO BREAK RETURN) ..	17
6 LOAD SHARING	18
6.1 ACTIVE POWER SHARING	18
6.2 REACTIVE POWER SHARING	18
7 THE NEED FOR SYNCHRONISING	19
8 METHODS OF ADJUSTING VOLTAGE & FREQUENCY.....	20
8.1 REMOTE SPEED / VOLTAGE POTENTIOMETERS	20
8.2 DC VOLTAGE INPUT	20
8.3 RAISE / LOWER PUSH BUTTONS.....	20
8.4 CAN / ELECTRONIC ENGINE SPEED CONTROL	21
9 REQUIREMENTS FOR SYNCHRONISING	22
9.1 GOVERNOR WITH REMOTE SPEED CONTROL CAPABILITY	22
9.2 AVR WITH REMOTE VOLTAGE ADJUST CAPABILITY.....	22
9.3 FUNCTION COMPARISON CHART.....	23
9.4 SYNC / LOAD SHARE PROTECTION COMPARISON CHART	24
10 LOAD SWITCHING DEVICES.....	25
10.1 CHOOSING A LOAD SWITCHING DEVICE	25
10.1.1 CONTACTORS	25
10.1.2 CHARGED SPRING BREAKERS	25
10.1.3 AIR CIRCUIT BREAKERS (ACBS)	25
10.1.4 MOTOR OPERATED BREAKERS	26
10.1.5 MANUALLY OPERATED BREAKERS	26
10.2 NEUTRAL EARTHING	26

11	MULTI SET COMMUNICATIONS (MSC) LINK	27
11.1	SYNCHRONISING	27
11.2	LOAD SHARING	27
11.3	START/STOP ON LOAD DEMAND.....	27
11.4	COMPATIBILITY.....	27
11.5	CONNECTIONS	28
11.6	SPECIFICATIONS.....	29
11.7	MSC ALARMS	30
11.7.1	MSC ID ALARM	30
11.7.2	MSC DATA ERROR	30
11.7.3	MSC FAILURE	30
11.7.4	MSC TOO FEW SETS.....	30
12	LOAD SHARE LINES.....	31
12.1	TYPICAL P123 INSTALLATION	31
13	TYPICAL CONNECTIONS	32
13.1.1	TYPICAL SINGLE LINE DIAGRAM OF MULTI SET MAINS FAIL	32
13.1.2	SINGLE LINE DIAGRAM OF MULTI MAINS SYSTEM.....	33

2 INTRODUCTION

A general overview of generator uses is given including synchronising. This is only to be treated as a guide to newcomers to this particular subject, and should not be treated as a total learning package.

Part 2 of this manual details the interfacing the DSE controllers with many of the most common AVRs and Governors in use on generating sets.

3 STEP BY STEP GUIDE

This section details the main steps that need to be taken in producing a synchronising / load sharing system. This is intended as a guide only and is not a substitute for in depth knowledge of synchronising and load sharing.

- Identify your base application. Applications supported by the DSE controllers are detailed in the section headed 'Synchronising and load sharing solutions'.
- Identify your governor and AVR interface methods. Details of this are contained in the sections headed 'Interfacing to governors' and 'Interfacing to automatic voltage regulators'.
- Design your panel and system wiring. DSE can assist with your specific questions on this but cannot design the panel for you. If you want a panel designing, please contact DSE Technical Support Department who may be able to recommend a third party panel designer / builder capable of producing a synchronising / load sharing system.
- Check / adjust the module's configuration using the PC configuration software. If it is a MultiSet system, ensure that the settings for the MultiSet Communications Link are correctly configured and the MultiSet communications cable is of the correct specification.
- Commission each set in the system as a single standalone set. Before doing this, ensure the governor/AVR interface is disabled as detailed in the section entitled 'On site commissioning'.
- Set up the governor and AVR as detailed in their respective manufacturers' handbooks.
- Before synchronising sets for the first time, double check that all the Bus wiring is correct and that the controllers initial settings are suitable. This may include lowering the settings for 'gain' and 'stability' in the synchronising, voltage matching and load control sections.

Further detailed information on this subject is contained in the DSE Load Share Design and Commissioning Guide (DSE PART 057-047).

Should you have any queries arising from this manual please contact our Technical Department:

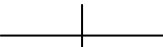
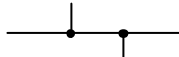
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3.1 CLARIFICATION OF NOTATION AND TERMINOLOGY USED WITHIN THIS PUBLICATION.

	NOTE:	Highlights an essential element of a procedure to ensure correctness.
	CAUTION!	Indicates a procedure or practice which, if not strictly observed, could result in damage or destruction of equipment.
	WARNING!	Indicates a procedure or practice, which could result in injury to personnel or loss of life if not followed correctly.
		DEEP SEA ELECTRONICS PLC own the copyright to this manual, which cannot be copied, reproduced or disclosed to a third party without prior written permission.
		Compliant with BS EN 60950 Low Voltage Directive Compliant with BS EN 50081-2 EMC Directive Compliant with BS EN 50082-2 EMC Directive
		Two crossing wires with no interconnection between the two.
		Three wires, all connected together
		Connections to the DSE controller's battery supply negative terminal, usually the earthed battery –ve terminal.
A.V.R.		Automatic Voltage Regulator. Fitted to the alternator to regulate the output of the generator.
Governor		Engine Speed Governor. Fitted to the engine to electronically control the speed of the engine.
Droop		When load is applied to a generator fitted with a droop governor / AVR, the speed/voltage will drop. This is called droop. It is common for a droop set to drop between 3% and 10% in speed / voltage from no load applied to full load applied.
Isochronous		A governor with no speed droop, or where speed droop is disabled is known as an isochronous governor. The engine speed remains constant so long as the load levels are within the set's capability.
Synchronise		To get the supplies identically matched, ready for paralleling.
Parallel		Connect two or more supplies together. These supplies must be in synchronism before this can occur.
Datum		'centre' point of an electronic pot, digital resistance or AVR/Governor.
Nominal		The nominal voltage or frequency of the system i.e. 230V 50Hz. This is not necessarily the same as the Datum. (i.e. when droop governors/AVRs are used, the datum will be higher than the nominal)
Mains supply		The AC distributed power supply of a power generation company. Often also called the 'grid', or 'utility' supply.

4 GENERATOR USES

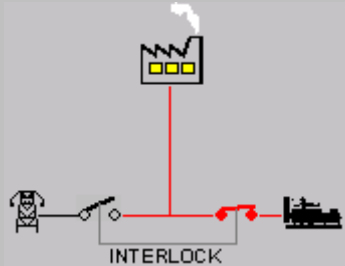
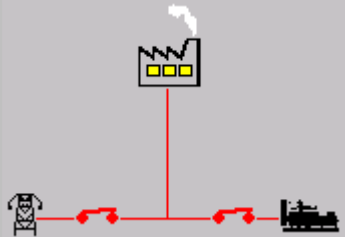
AC Power Generators are widely used to supply power to a load at “mains” voltage levels. Most people first encounter a generating set when used as the primary power source. An example of this is the small trailer mounted generators often seen in use supplying power to highway maintenance equipment.

Other terms used to describe a generator as the sole supply are ‘Primary power’ or ‘Prime power’. Knowledge of prime power generation in this way is assumed and is not covered within this manual.

4.1 STANDBY GENERATORS

Generators are commonly used as a backup to the mains supply. Due to their nature, backup supply generators are rarely seen by the public! Should the mains supply fail, the generator will be started and used to provide power until it returns. Applications include factories, offices, schools, emergency services (including hospitals), airports, telecommunications providers etc.

Backup generators fall into two main categories:

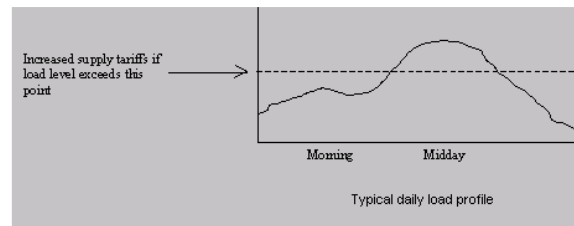
Illustration	Description
4.1.1 TRANSFER SWITCH 	The most common form of backup generator to the mains supply is a single generator in “standby” mode. When the mains supply fails, the load is left without power until the generator is started. Once the set is “available”, the transfer switch changes over so that the load is supplied by the generator. Typically, the “down time” will be around 15 seconds, but may be longer depending upon the time taken to run the engine to nominal speed and other application dependent factors. When the mains supply returns, the load-switching device (contactors/breakers) will momentarily remove power from the load (typically 1 second) before transferring the load back to mains supply power.
4.1.2 NO BREAK TRANSFER 	The break in supply when transferring back to the mains can be eradicated by synchronising the generator supply to the returned mains supply, and closing the supplies in parallel with each other for a short period of time. Then, the generator load switch is opened, returning the mains to supply power to the load. There has been no break in supply to the load during this return transfer process. Terms often used for this procedure are “bumpless transfer”, “no break return” and “no break transfer”. Additionally, the same procedure can be used to transfer from mains supply to generator supply enabling, for instance, “on load” testing of the genset with no break in supply to the load. This can also be performed if the supply authority informs customers of a scheduled break in supply.

4.2 CONTINUOUS PARALLEL OPERATION

Electricity supply boards have many tariffs based upon the customer's load demand. In some cases, the tariffs can treble or more during certain times of the day if a specific load level is exceeded.

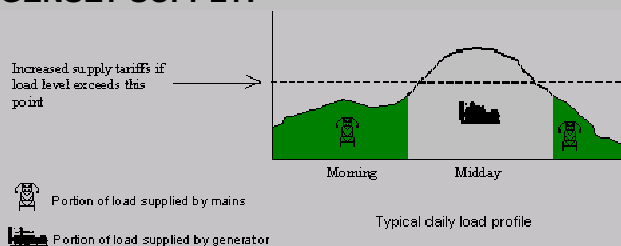
In this example, the customer is charged more for his electricity in the hours around midday, as his load level places his power usage into the next charging tariff.

In some cases, it can be more cost effective for the customer to provide an alternative power supply during this time of high tariff. There are a number of possibilities open to him:



Illustration

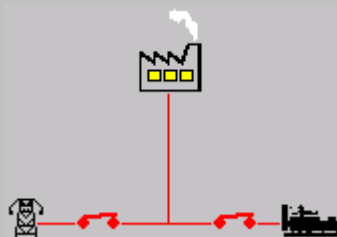
GENSET SUPPLY.



Description

During the time of high load level a single (or multiple) generator(s) could be started, and then used to power the load using a 'no break' transfer. This genset supply must be capable of supplying the entire load during this time of high usage.

4.3 BASE LOAD WITH DSE '20 CONTROLLER



In this example, a DSE '20 controller is being used in a base load peak lopping system. The controller has been configured to start the generating set at 10am, synchronise with the mains and parallel the supplies. It will then export a fixed amount of power (kW) to the load and maintain a specified power factor (both configurable). If the set is large enough to supply the entire load, mains failure duty is also available.

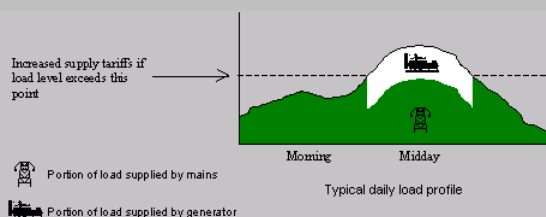
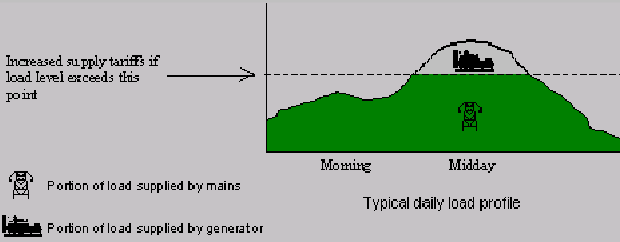


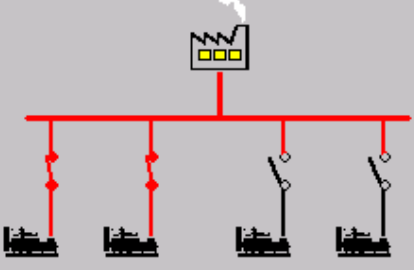
Illustration	Description
4.3.1 TRUE PEAK LOPPING AND IMPORT/EXPORT CONTROL  Increased supply tariffs if load level exceeds this point Portion of load supplied by mains Portion of load supplied by generator Morning Midday Typical daily load profile	A more advanced variation of the peak lopping system described above is to use a 7520 (for single set) or DSE8610 with DSE8660 (up to 32 sets). In this situation variable Peak Lopping or true import/export can be achieved. The DSE8660 or DSE7520 will monitor the site load levels and vary the generator(s) power production. This can be used to ensure the set is used at its economic load level, and prevents the system exporting power. It can also be used to hold the mains usage to a certain level (DSE Mains Mode), helping to avoid higher electricity board tariffs or supplementing the mains supply on a site with limited supply available.

NOTE: - It is recommended that the mains decoupling is enabled in the DSE module when paralleling a generating set with the mains. Additional equipment of this type is normally specified by the local electricity Supply Company to protect against the generator feeding the mains grid in the case of a mains failure. If in doubt, you should refer to your local Electricity Supply Company for advice.

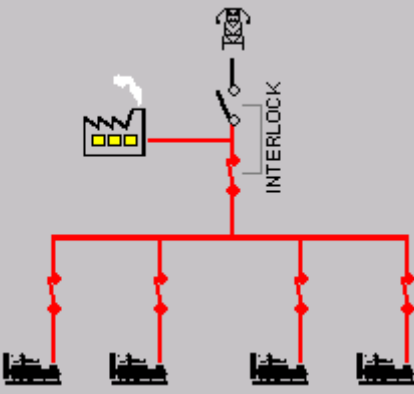
NOTE: - Mains decoupling functionality is included within the DSE8600 and DSE8700 series controllers. DSE 7500 and DSE 5500 include this function in versions 8 or above. When using other controllers, this functionality should be provided externally. Additional equipment of this type is normally specified by the local electricity Supply Company to protect against the generator feeding the mains grid in the case of a mains failure. If in doubt, you should refer to your local Electricity Supply Company for advice.

4.4 MULTIPLE GENERATORS

There are many reasons for requiring more than one generator on the same site.
The most common reasons are described below:

Illustration	Description
4.4.1 MULTIPLE SET PRIME POWER 	In this example, the site has four generating sets, used as the primary power source. One genset will be running all the time, to provide power to the site. If the load demand of the site increases, one or more generators will be automatically called to start. They will then synchronise onto the bus, and provide power in parallel with the other set(s). At this point, the sets connected to the bus will share the load, normally utilising load sharing equipment. Using multiple generating sets rather than one large set allows for maintenance to be performed on one of the sets while the other set(s) are still available for duty. Additionally, if load demands are low, individual generators can be started as required, rather than one large generator being used at (for instance) only 25% of its full load rating. If the overall size of the load increases, for instance due to factory expansion another set can be added to increase capacity with minimal disruption to the rest of the system. Using this system, “redundancy” can be built in by utilising a larger number of gensets than is required to supply the load. This way, the load can still be supplied if one or more sets are unavailable due to engine failure or maintenance. The DSE controllers have “no master” ensuring a seamless transition when one or more sets are removed from the system.

4.4.2 MULTIPLE SETS PROVIDING STANDBY TO THE MAINS SUPPLY

Illustration	Description
	If multiple gensets in parallel are used to backup the mains supply, care should be taken when designing the system. In the example above for instance, should the mains supply fail, two possibilities exist. Firstly, if only two generating sets are providing power to the bus, they must be capable of supplying the currently active load. Secondly, if none of the sets are available, they will all start up simultaneously. The first set will close onto the dead bus, and supply power to the load. Again, the set must be capable of supplying this power to the currently active load. Two solutions exist : - Ensure each generating set is capable of supplying the entire load so that the above situations will not occur. - Ensure before closing the load switch and powering the load with the generating sets, that all of the generating sets are available and synchronised onto the generator bus. While running in this manner, not in parallel with the mains supply, this is called 'island mode'.

4.4.3 LOAD-SWITCHING USING DSE333 ATS (BREAK TRANSFER)

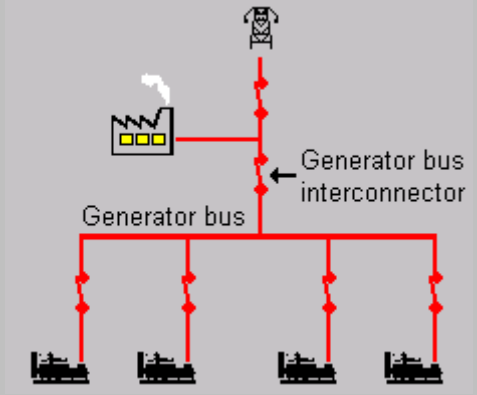
The DSE333 automatic transfer switch can be used to monitor the mains supply to ensure it is within limits. Should the mains supply fail, the 333 can be used to 'remote start on load demand' the DSE8610 controllers used in the example shown. All sets in the system will start together. The first available set will close onto the dead bus. The other generating sets will synchronise onto the generator bus, and then close in parallel with it.

Configure and output of the DSE8610s to *all available sets on load* and connect them all to the *auxiliary generator ready* input DSE333 automatic transfer switch.

The DSE333 module will sense the generator bus voltage and frequency, and once within limits will 'wait' for the presence of the *auxiliary generator ready* input. This signifies the correct closure of all sets in the system onto the generator bus. The mains – generator load transfer is then performed by the DSE333 automatic transfer switch controller.

Note that this functionality can be provided by any of the DSEAts range of controllers.

4.4.4 MULTIPLE SETS (STANDBY) – NO BREAK TRANSFER

Illustration	Description
	In the example above, it was not possible to perform no break transfers to/from the mains supply. If a DSE8660 'mains controller' is fitted, to monitor the mains supply and power supplied by the mains to the load, additional possibilities exist, the most important of which are : 1) Should the mains supply fail, DSE8660 can call for the generating sets, which will synchronise and close onto the generator bus. When the sets are available on the generator bus DSE8660 can close the generator bus interconnecting load switch. When the mains supply returns, the generator bus can be synchronised and closed in parallel with it, to allow a no break return to the mains supply. 2) As the power being supplied by the mains is also being monitored, the DSE8660 can pass this information to the generator controllers, allowing load sharing between the generator bus and the mains supply. 3) No-break on load testing is possible, by calling for generators to start. The first to become available will close onto the dead generator bus, the remaining generators synchronising with the now live generator bus and closing in parallel with it. The DSE8660 will then communicate with the generating set controllers to effect synchronism of the generator bus with the mains supply. When synchronism has been achieved, the DSE8660 can close the supplies in parallel.

4.4.5 MULTIPLE MAINS SUPPLIES

Due to local electrical supply conditions or historical growth of the load, it is possible for the load to be fed by more than one incoming AC mains supply. Normally each mains supply will feed a separate part of the load. The DSE8660 module allows the standby generators to parallel with any one of the mains supplies at a time and will transfer the loads accordingly. Peak lopping is also possible on any one DSE8660 module in the system, in the event of a mains failure condition peak lopping can be automatically terminated to ensure the gen-sets are available for standby operation.

NOTE: - It is recommended that the mains decoupling is enabled in the module when paralleling a generating set with the mains. Additional equipment of this type is normally specified by the local electricity Supply Company to protect against the generator feeding the mains grid in the case of a mains failure. If in doubt, you should refer to your local Electricity Supply Company for advice.

NOTE:- Mains decoupling functionality is included within the DSE8600 and DSE8700 series controllers. DSE 7500 and DSE 5500 include this function in versions 8 or above. When using other controllers, this functionality should be provided externally. Additional equipment of this type is normally specified by the local electricity Supply Company to protect against the generator feeding the mains grid in the case of a mains failure. If in doubt, you should refer to your local Electricity Supply Company for advice.

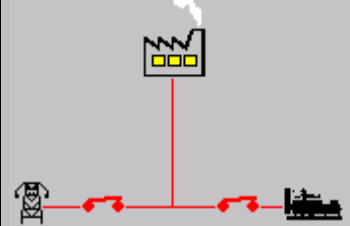
5 SYNCHRONISING AND LOAD SHARING SOLUTIONS

As the DSE synchronising and load sharing controllers can be used in many varying configurations, this chapter explains how the controllers are utilised and what controller options must be fitted. Where droop governors or AVR's are required, this is also mentioned. A more detailed description on synchronising and load sharing follows this section.

5.1 SINGLE SETS

5.1.1 SINGLE SET NO BREAK RETURN WITH MAINS

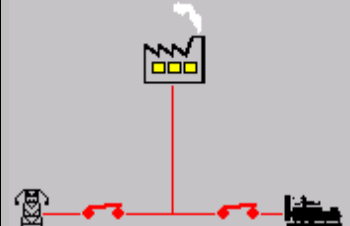
A single set primarily used to provide backup to the mains supply should it fail. When the mains supply returns, the generator is synchronised to the mains supply and momentarily closed in parallel with it before opening the generator load switching device.

	Controller :	8620 7520 5520
	Load Share options :	• <i>Generator Mode</i> (Fixed export or Base load) • <i>Mains Mode</i> (Import / Export control or peak lopping)

NOTE: - It is recommended that the mains decoupling is enabled in the DSE module when paralleling a generating set with the mains. Additional equipment of this type is normally specified by the local electricity Supply Company to protect against the generator feeding the mains grid in the case of a mains failure. If in doubt, you should refer to your local Electricity Supply Company for advice.

5.1.2 SINGLE SET FIXED EXPORT

A single set used solely to parallel with the mains. No control of the mains breaker is provided. If the mains breaker opens, the decision must be made if the set can be used to power the load (if the set is large enough). Upon mains return, the set breaker must be opened before the mains breaker can be closed.

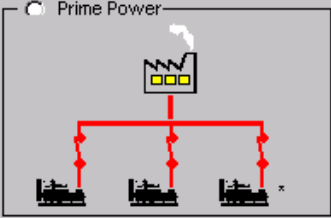
	Controller :	8610 8710 7510 5510
	Load Share options :	• Fixed export through <i>Mains parallel mode</i> operation of the DSE '10 controller.

NOTE: - It is recommended that the mains decoupling is enabled in the DSE module when paralleling a generating set with the mains. Additional equipment of this type is normally specified by the local electricity Supply Company to protect against the generator feeding the mains grid in the case of a mains failure. If in doubt, you should refer to your local Electricity Supply Company for advice.

5.2 MULTIPLE SETS

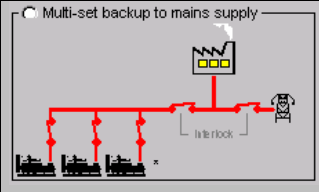
5.2.1 MULTIPLE SET PRIME POWER

Two or more sets are used to provide power to the load, sharing power equally as a percentage of the sets full load rating. Sets are automatically started and stopped depending upon load levels allowing economic use of the available generators.

 Prime Power	Controller :	8610 (max 32 set system) 8710 (max 32 set system) 7510 (max 16 set system) 5510 (max 16 set system)
	Load Share options :	Full control of the kW/KVAr load share is possible, the sets equally sharing the kW load between them pro rata (i.e. same percentage of their rating). NOTE: - DSE8610 and DSE8710 are compatible in the same system. DSE5510 and DSE7510 are compatible in the same system. HOWEVER – DSE8610 and DSE8710 cannot be used in the same system as DSE5510 or DSE7510. A DSE125 MSC is used to interface these two devices together. Contact DSE for further advice.

5.2.2 MULTIPLE SET STANDBY TO MAINS SUPPLY (BREAK RETURN)

Two or more sets are used to provide backup to the mains supply. When the mains supply fails, the sets are started, synchronised and paralleled together. The generators bus is then closed to feed the load, the sets sharing power equally as a percentage of their full load rating. Sets are automatically started and stopped depending upon load levels allowing economic use of the available generators. When the mains supply returns, there will be a break in supply to the load while the transfer takes place.

	Controller :	8610 (max 32 set system) 8710 (max 32 set system) 7510 (max 16 set system) 5510 (max 16 set system) DSE333 ATS controller
	Load Share options :	• DSE333 handles BREAK change between mains / generator bus. NO PARALLEL operation with mains is possible. • Full control of the kW/KVAr load share is possible, the sets equally sharing the kW load between them pro rata (i.e. same percentage of their rating). ⚠ NOTE: - DSE8610 and DSE8710 are compatible in the same system. DSE5510 and DSE7510 are compatible in the same system. HOWEVER – DSE8610 and DSE8710 cannot be used in the same system as DSE5510 or DSE7510. A DSE125 MSC is used to interface these two devices together. Contact DSE for further advice.

5.2.3 MULTIPLE SET STANDBY TO MAINS SUPPLY (NO BREAK RETURN)

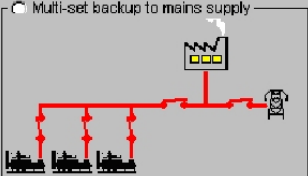
Two or more sets are used to provide backup to the mains supply. When the mains supply fails, the sets are started, synchronised and paralleled together. The generators bus is then closed to feed the load, the sets sharing power equally as a percentage of their full load rating. Sets are automatically started and stopped depending upon load levels allowing economic use of the available generators. When the mains supply returns, there will be **NO** break in supply to the load while a ramped transfer takes place.

A DSExx60 controller is connected to the load share controllers via the **Multi Set Communications** link and monitors the mains supply, signalling all available sets to start should the supply fail. Additionally the controller will start the sets if the mains load reaches a configurable level to provide peak lopping and import/export control.

All available sets will start and after the *minimum number of sets* have successfully paralleled with each other, the controller will transfer the load to the generator bus.

The generators will then share the load using their load sharing communications link, sets being stopped / started depending upon load demands (if enabled)

Upon mains restoration, the controller will synchronise the generator bus to the mains and ramp the load back to the mains. The sets are then instructed to cool down and stop.

	Controller :	DSE8610 (max 32 set system) DSE8710 (max 32 set system) DSE8660 or DSE8760 mains controller 7510 (max 16 set system) 5510 (max 16 set system) DSE7560 or DSE5560 mains controller
	Load Share options :	• DSExx60 handles mains monitoring and soft transfer between mains / generator bus. • Full control of the kW/KVAr load share is possible, the sets equally sharing the kW load between them pro rata (i.e. same percentage of their rating). • <i>Generator Mode</i> (Fixed export or Base load) • <i>Mains Mode</i> (Import / Export control or peak lopping) NOTE: - DSE86xx and DSE87xx are compatible in the same system. DSE55xx and DSE75xx are compatible in the same system. HOWEVER – DSE86xx and DSE87xx cannot be used in the same system as DSE55xx or DSE75xx. A DSE125 MSC is used to interface these two devices together. Contact DSE for further advice.

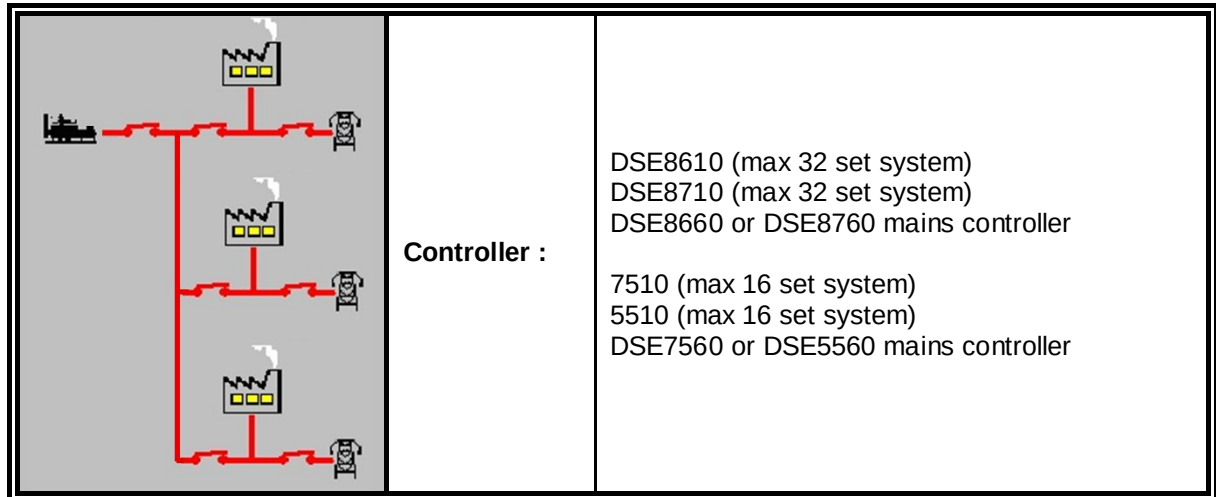
5.2.4 MULTIPLE MAINS SUPPLIES

5.2.5 SINGLE SET STANDBY TO MULTIPLE MAINS SUPPLY (NO BREAK RETURN)

Set(s) are used to provide backup to multiple mains supplies. Should one of the mains supplies fail, the set is started, and the appropriate load is transferred to the generator set. Should further mains supplies fail, the appropriate loads will also be transferred to the generator.

Should one of the mains supplies return, there will be **NO** break in supply to the load while a ramped transfer takes place. This will be repeated for each returning mains supply until the generator set is transferred off load and finally stopped.

The order of the mains restoration depends upon module priority and operating state. This priority is covered in the DSExx60 operator manual.



6 LOAD SHARING

6.1 ACTIVE POWER SHARING

We have discussed the synchronising of one or more supplies to the mains or bus supply. Once these supplies are closed in parallel with each other, the power will be shared between the supplies depending upon the generating set characteristics.

Control over the set's active power is achieved by controlling the amount of fuel into the engine. Instructing the governor to increase fuel to the engine will also have little or no effect on engine speed because the generator is "tied" to the other supply. Instead, the generator will supply more power to the load. This in turn decreases the amount of power provided by the other supplies. This is known as Kilowatt (kW) control.

This can be taken a step further, by paralleling multiple generating sets, all operating isochronously (zero droop). Utilising an active load-sharing controller such as the **DSE8610**, precise changes can be made to the amount of power supplied to the load by each generating set. This is achieved by altering the amount of fuel supplied to the engine, and monitoring the amount of power supplied by the set.

Each controller can communicate with the others, passing information regarding load levels. This can also be used to bring in or drop off other generating sets as load demands change.

6.2 REACTIVE POWER SHARING

Again, consider two identical generating sets closed together in parallel.

Adjusting the amount of field excitation in one of the generators has the effect of that generator supplying more or less of the reactive power to the load, matched by an equal drop in the reactive power supplied by the other generator.

Reactive power is the power used to supply inductive or capacitive load.

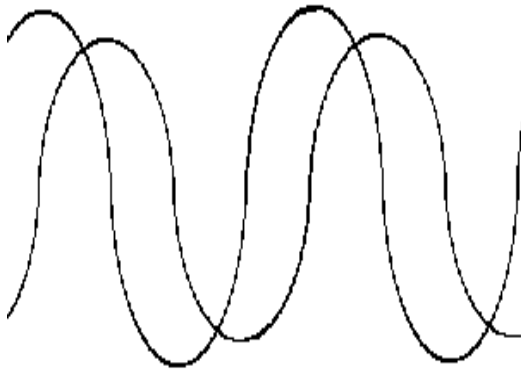
Uses of reactive power control include:

- 1) Where multiple generators are used in parallel with each other, the reactive power is equalised between the sets, removing circulating currents caused by imbalance in the reactive power (VAr) supplied by the paralleled generating sets. This circulating current can generate heat in the alternator windings. If left unchecked, excess circulating current can also damage the alternator windings.
- 2) Power factor control or VAr control. This feature maintains a specific power factor where one generating set is used in parallel with the mains supply. This is normally used so that the generator maintains its VAr to keep its output at the site load's average power factor level, to minimise demands on the mains supply.

7 THE NEED FOR SYNCHRONISING

Before two or more A.C. supplies can be 'closed' together in parallel, the frequency, voltage and phase of the supplies must be matched as closely together as possible. Collectively, frequency and voltage matching are known as synchronisation, although voltage matching may not be required in all applications.

Additionally, the phase rotation of the supplies must be the same, i.e. L1, L2, L3 (Anticlockwise rotation) or L3, L2, L1 (Clockwise rotation). The DSE synchronising and load sharing modules will check the phase rotation. If this is wrong, the controller can not act, apart from notifying the operator with an alarm condition. The fault must be corrected before synchronising of the supplies can be attempted.



Synchronisation is achieved firstly by adjusting the engine speed and generator voltage to get the frequency and voltage of the generator closely matched to that of the bus / mains supply.

Then the phase angle of the supplies is monitored until it is within an acceptable 'window' before the supplies can be closed together in parallel.

In the example to the left, the two supplies (shown by the two sine waves) have very similar frequencies (seen as the distance between the "peaks" of the waves). However, they have very different voltages (overall heights of the waves) and the supplies are not in phase (the two supply waves are not "on top" of each other).

Typically, a frequency difference (called slip frequency) of 0.1Hz, a voltage difference of 5% and a phase angle of 5° will allow for satisfactory paralleling of the supplies.

Once the supplies are closed in parallel, the phase of the supplies will not alter, they are 'locked' in parallel together.



WARNING! Attempting to close the supplies in parallel when they are not in synchronism can result in damage to the generating set system.

For example: If synchronising (using two gensets) is effected 120° out of phase, the coupling torque can be as high as 12 times full load torque, depending on the ratio of engine and generator inertias (Source: Diesel Generator Handbook L.L.J. Mahon).

The actual synchronising process can be achieved through various methods. Put simply, each method involves manipulating the engine governor to increase/decrease engine speed (which has a direct relationship with generator frequency) and the Automatic Voltage Regulator (which controls the alternator excitation field to produce voltage).

The engine governor determines engine speed, by sensing the speed of rotation of the flywheel (normally using a magnetic pickup probe). The governor can then control the actuator to adjust the amount of fuel into the engine, which changes engine speed (similar to the accelerator in a car). Most governors are also fitted with a 'remote speed adjust' input to allow an external device to increase or decrease the set speed of the engine.

The Automatic Voltage Regulator effects change in the generator output voltage by controlling the alternator's exciter field. The AVR adjusts the voltage output to the required set voltage. Most AVRs are also fitted with a 'remote volts adjust' input to allow an external device to increase or decrease the set voltage of the alternator.

Automatic synchronisers act upon the 'remote speed adjust' and 'remote volts adjust' inputs of the governor and AVR to affect synchronism and voltage matching.

The method of interface between the automatic synchroniser and the governor/AVR depends upon the type of governor and AVR being used, and are described in the section entitled "Methods of Adjusting Voltage and Frequency".

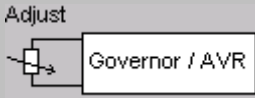
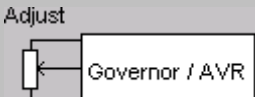
8 METHODS OF ADJUSTING VOLTAGE & FREQUENCY

8.1 REMOTE SPEED / VOLTAGE POTENTIOMETERS

The most common way to remotely adjust engine speed/generator voltage is by speed/voltage potentiometers. These are fitted to the control panel to allow the operator to adjust the supply to the parameters required and connect directly to most AVRs/Governors, which are fitted with terminals designed for the purpose.

A simple way to replace this manual operation with an automatic one is by utilising a motor driven potentiometer, which is adjusted automatically by the synchronising controller.

Two popular methods of interfacing with potentiometers have been adopted by AVR/Governor manufacturers and are commonly shown on their 'connection diagrams' as shown in the following examples:

Illustration	Description
Variable resistance 	This diagram shows a two terminal connection to the governor/AVR. The value of the variable resistor (rheostat) depends upon the requirements of the governor/AVR being used. This type of interface is suitable for connection direct to the analogue governor output of the DSE8610 or DSE8710 controllers.
Potentiometer 	This diagram shows a three terminal arrangement, for connection to a potentiometer. The value of the potentiometer depends upon the requirements of the governor/AVR being used. This type of interface is usually suitable for connection direct to the analogue governor output of the DSE8610 or DSE8710 controllers.

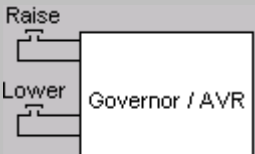
8.2 DC VOLTAGE INPUT

Another analogue interface often used by governor manufacturers utilises a DC voltage, the level of which is proportional to the engine speed required. An example of this is the G.A.C.ESD5500E that accepts a DC signal from 2V to 8V to represent adjustment away from the set speed point. When the DC level is at 5V, the engine speed is the governors' set speed.

This type of interface is suitable for connection direct to the analogue governor output of the DSE8610 or DSE8710 controllers.

8.3 RAISE / LOWER PUSH BUTTONS

Push buttons to raise/lower the engine speed / alternator output voltage can also be used. The push buttons are fitted to the control panel and allow step changes in voltage / frequency with a single press of the button.

Illustration	Description
RAISE / LOWER PUSH BUTTONS 	This diagram shows switched inputs to the governor/AVR to raise/lower speed/voltage. This type of interface is suitable for direct connection to outputs configured to raise/lower DSE8610 or DSE8710 controllers, though it is usual to fit interposing slave relays between the controller and the governor/AVR to provide isolation between the devices.

NOTE:- Governor and AVR connections are covered in detail (including typical connection for commonly used governors and AVRs) in the DSE Guide to Synchronising and Load Sharing Part 2.

8.4 CAN / ELECTRONIC ENGINE SPEED CONTROL

Some electronic engine ECUs support speed control via the CAN data interface negating the requirement to connect additional speed control signals to the speed controller.

This feature is supported by the DSE8700, DSE8600, DSE7500 and DSE5500 series controllers.



NOTE:- Connections to electronic engine ECUs are detailed in the DSE publication *Electronic Engines and DSE wiring* and the *Guide to Synchronising and Load Sharing Part 2*.

9 REQUIREMENTS FOR SYNCHRONISING

9.1 GOVERNOR WITH REMOTE SPEED CONTROL CAPABILITY

This can be an electronic governor with either analogue (preferred) or digital (raise/lower inputs) to control engine speed. Alternatively it could be an electronic engine ECU (CANbus for instance) that supports speed control over the engine data link (CAN) or via analogue / digital control signals. You should check with the engine supplier about these possibilities.

If you use digital raise/lower inputs you must have droop configured in the governor. If you use analogue or CAN for speed control, it is usual to disable governor droop.

9.2 AVR WITH REMOTE VOLTAGE ADJUST CAPABILITY

This can be an Automatic Voltage Regulator with either analogue (preferred) or digital (raise/lower inputs) to control generator output. You should check with the alternator supplier about these possibilities.

The alternator manufacturer will usually demand that a Droop Kit is fitted to the alternator to maintain warranty if you are paralleling with another set. While this is recommended, it is not always necessary. Again, you should consult with the alternator manufacturer if in any doubt.

If an AVR with remote voltage adjust capability does not exist, you may still be able to load share. You will need to fit a Droop Kit to the AVR. In this instance, no voltage matching will take place and rudimentary VAr (reactive power) sharing will take place using the droop kit. The DSE module will not control the AVR.

Function comparison chart

9.3 FUNCTION COMPARISON CHART

(Current production DSE modules)

	8610 load share	8620 load control	8660 mains controller	8710 load share	8760 mains controller	7510 load share	7520 load control	7560 mains controller	5510 load share	5520 load control	5560 mains controller
Power measurement instrumentation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Auto synchronising	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Isochronous load sharing / control	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MultiSet communications	✓	✗	✓	✓	✓	✓	✗	✓	✓	✗	✓
Starts sets on rising mains load	✗	✓	✓	✗	✓	✗	✓	✓	✗	✓	✓
Automatic first set on the bus determination	✓	N/A	✓	✓	✓	✓	N/A	✓	✓	N/A	✓
Calls for more or less sets on changing load demands	✓	N/A	✓	✓	✓	✓	N/A	✓	✓	N/A	✓
Mains power monitoring	N/A	✓	✓	N/A	✓	N/A	✓	✓	N/A	✓	✓
Adjustable priority	✓	N/A	✓	✓	✓	✓	N/A	✓	✓	N/A	✓
Automatically balances run hours (multiset system)	✓	N/A	✓	✓	✓	✓	N/A	✓	✓	N/A	✓
RS232 option available?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RS485 option available?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Configurable LEDs?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Interface to governor/AVR	Inbuilt analogue output	Inbuilt analogue output	N/A	Inbuilt analogue output	N/A	Inbuilt analogue output	Inbuilt analogue output	N/A	Inbuilt analogue output	Inbuilt analogue output	N/A
Load switch push buttons?	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons	Inbuilt fascia buttons, also available using digital inputs and external buttons
PC configuration software	DSE Configuration Suite	DSE Configuration Suite	DSE Configuration Suite	DSE Configuration Suite	DSE Configuration Suite	5xxx for Windows	5xxx for Windows	5xxx for Windows	5xxx for Windows	5xxx for Windows	5xxx for Windows
Remote Comms software	DSE Configuration Suite or DSE SCADA Suite	DSE Configuration Suite or DSE SCADA Suite	DSE Configuration Suite or DSE SCADA Suite	DSE Configuration Suite or DSE SCADA Suite	DSE Configuration Suite or DSE SCADA Suite	Link5000Plus	Link5000Plus	Link5000Plus	Link5000Plus	Link5000Plus	Link5000Plus
Inbuilt PLC	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗

9.4 SYNC / LOAD SHARE PROTECTION COMPARISON CHART

(Current production DSE modules)

	8610 load share	8620 load control	8660 mains controller	8710 load share	8760 load share	7510 load share	7520 load control	7560 mains controller	5510 load share	5520 load control	5560 mains controller
Phase rotation protection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dead bus relay	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Frequency check	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Voltage check	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Phase angle check	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fail to synchronise alarm	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Generator reverse power	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mains reverse power	✗	✓	✓	✗	✓	✗	✓	✓	✗	✓	✓
Loss of excitation protection	✓	✓	✗	✓	✗	✓	✓	✗	✓	✓	✗
Earth fault protection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Negative phase sequence protection	✓	✓	✗	✓	✗	✓	✓	✗	✓	✓	✗
Vector shift	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R.O.C.O.F.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

 **NOTE:-** With DSE5500 series controllers, Mains decoupling, Vector shift and R.O.C.O.F. is fitted internally to versions 8.0 and above only.

 **NOTE:-** Model 5560 must be used in conjunction with one or more 5510 controllers. It is not a stand alone module.

10 LOAD SWITCHING DEVICES

The paralleling of two or more supplies requires that the switching of the supplies be performed as close to zero phase as possible. The check sync feature of the DSE synchronising and load sharing controller can accurately measure the phase, and when within the 'check sync' window can issue the load switching closure signal within a few milliseconds. However, there will be a delay in the actual operation and physical movement of the switching device that must be minimised and taken into account when designing and commissioning any paralleling system.

10.1 CHOOSING A LOAD SWITCHING DEVICE

It is typically considered that load switching for parallel supplies be performed within 5 supply cycles of the close signal being given to ensure the phase or the supplies has not changed too greatly after the closing signal has been given.

	Cycle time	Max load switch closing time
50Hz system	20.0 ms	100 ms
60Hz system	16.7 ms	83 ms

 **NOTE:** - The closing time of any load switching device slave relays should also be taken into account. For instance, plug in relays typically used in generating set control panels have an operation time of 10ms-20ms.

 **NOTE:** - If fitting a mains (utility) 'Breaker' with a trip position, it is recommended to fit one equipped with auxiliary contacts to indicate the "tripped" position. This can be fed into an input configured to "auxiliary mains failure" so that the module is 'informed' of mains (utility) supply breaker tripping should this occur. This is particularly important when the module is operating in parallel with the mains (utility) supply.

 **WARNING!:** Manually operated breakers CANNOT be used as they cannot be operated within the required closing time.

10.1.1 CONTACTORS

Contactors normally operate fast enough for paralleling applications but care should be taken to choose a contactor that the manufacturer specifies be fast enough for use in paralleling applications. (See above).

10.1.2 CHARGED SPRING BREAKERS

In general, charged spring breakers will operate much faster than contactors. Charged spring breakers 'pre charge' a large spring device within the breaker, so that when breaker operation is required, the spring is 'released' which operates the closing action of the device.

Typically, the spring is charged when the undervolts input is energised, normally when the set is first started. Once charged, the breaker is ready for the closing signal.

10.1.3 AIR CIRCUIT BREAKERS (ACBS)

A.C.B.'s normally operate fast enough for paralleling applications but care should be taken to choose an A.C.B. that the manufacturer specifies be fast enough for use in paralleling applications. (See above).

10.1.4 MOTOR OPERATED BREAKERS

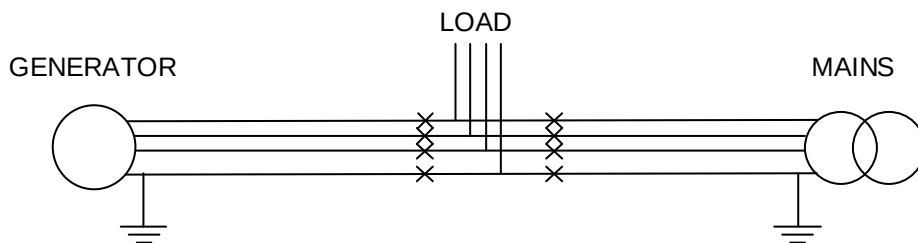
Some types of motor operated breakers are not suitable for paralleling operations due to the excessive amount of time that the breaker takes to motor into position before the closing process can be completed. Care should be taken to choose a motor operated breaker that the manufacturer specifies be fast enough for use in paralleling applications. (See above).

10.1.5 MANUALLY OPERATED BREAKERS

As these cannot be closed within the required time, manually operated breakers cannot be used.

10.2 NEUTRAL EARTHING

Where the generator star point (Neutral conductor) is connected to earth, care must be taken to avoid *earth loops*. This is of particular importance when paralleling a generator with other sets or with the mains supply.



This diagram shows a typical situation where the generator neutral conductor is earthed. The mains neutral conductor is earthed by the supply company. If the generator is placed in parallel with the mains supply, the neutral will be earthed at two points, creating an earth loop, which in turn generates current flow in the loop. To prevent this situation, the generator neutral earth link can be broken when the supplies are in parallel using a neutral earthing contactor in the neutral to earth link.

Similarly, when two or more sets are in parallel with each other, it is important to ensure that only one neutral to earth link exist in the system at any one time.

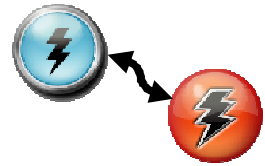
Control over the neutral earthing is not made by the DSE controller. Provision for this function must be made by external switching, often utilising auxiliary contacts of the load switching devices.

11 MULTI SET COMMUNICATIONS (MSC) LINK

The Multi Set Communications (MSC) link in use with DSE synchronising and load sharing modules performs many functions including load sharing and protection.

11.1 SYNCHRONISING

- o First Set on the Bus determination (Virtual Key)
- o Security against bus sensing failure (Broken fuse)



11.2 LOAD SHARING

- o Active (kW)
- o Reactive (kVAr)



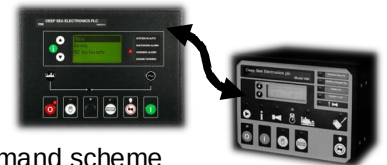
11.3 START/STOP ON LOAD DEMAND

- o Starting sequence
- o Run Priority
- o Balance engine hours
- o Control by DSE8660 / DSE7560 / DSE5560



11.4 COMPATIBILITY

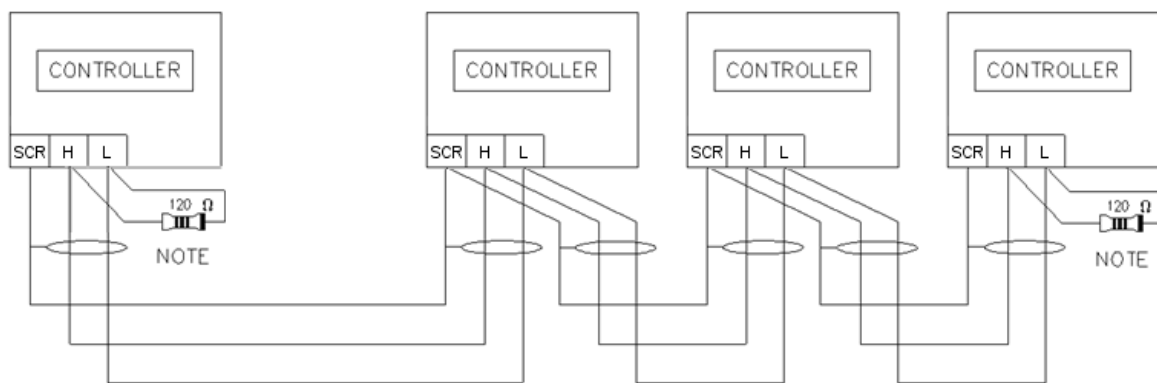
- o The load demand scheme uses the DSE controller's MSC link.
- o DSE7500 series are compatible with DSE5500 and DSE550 series controllers. For instance a DSE7510 controller can be used in a load demand scheme with a DSE5510 controller.
- o DSE8600 series controllers are NOT compatible with DSE7510, DSE5510 or DSE550 series controllers without the use of DSE125 MSC interface. Contact DSE for further advice.
- o Priority based upon engine hours is available on all DSE8610 and DSE7510 controllers. It is not available on DSE5510 controllers prior to Version 6 and is not available on DSE550 controllers.



For details of Run priority and balance engine hours, see DSE Part Number 056-013 Load Demand Scheme

11.5 CONNECTIONS

- o A maximum of 32 generator controllers (DSE8610) can be connected to the MSC link.
- o A maximum of 32 mains controllers (DSE8660) can be connected to the MSC link.
- o A combined maximum of 40 DSE8600 series controllers can be connected to the MSC link.
- o A maximum of 16 generator controllers (DSE7510 / DSE5510) can be connected to the MSC link.
- o A maximum of 16 mains controllers (DSE7560 / DSE5560) can be connected to the MSC link.
- o A combined maximum of 20 DSE7500 / DSE5500 series controllers can be connected to the MSC link.
- o DSE8620, DSE7520 and DSE5520 DO NOT connect to the MSC link and cannot be used in multiset systems or systems including DSE8660, DSE7560 or DSE5560
- o MSC is a high speed data transmission line. As such it must be wired in cable rated for such operation. DSE Stock and Supply Belden 9841 cable which is suitable for MSC link operation (DSE part number 016-030)
- o Ensure spurs off the MSC link are not used. The connections MUST be in 'daisy chain' fashion, with the cable entering, and leaving the 'middle' controllers as shown below.
- o Ensure termination resistors are fitted to the beginning and end of the MSC data link as shown below. A termination resistor is supplied in the box with every DSE controller that has an MSC link connection.
- o The maximum combined length of the MSC link must not exceed 240m (320yds). If further range is required, use DSE124 MSC Link Extender.



NOTE
A 120 OHM TERMINATION
RESISTOR MUST BE FITTED TO
THE FIRST AND LAST UNIT
ON THE DSEnet

11.6 SPECIFICATIONS

Parameter	Value
Connection type	Twin conductors with screen. Ensure screen is connected to SCR terminal of every controller on the bus.
Cable impedance	120Ω
Maximum cable resistance	0.050Ω/m
Maximum cable capacitance (between conductors)	75pF/m
Maximum cable capacitance (conductor to shield)	110pF/m
Termination resistors (one at each end of cable run)	120Ω 4W (supplied loose with controller)
Max number of 8610/8710 controllers per bus	32 (only 3 shown above for clarity)
Max number of 8660/8760 controllers per bus	32
Max number of 86xx + 87xx controllers per bus	40
Max number of 7510/5510 controllers per bus	16 (only 3 shown above for clarity)
Max number of 7560/5560 controllers per bus	16
Max number of 55xx + 75xx controllers per bus	20
Max number of 550 controllers per bus	16
Max number of 556 controllers per bus	1
Max cable length	250m
Max Spur length (see note 2 below)	1m
Recommended cable	* BELDEN 9841 120Ω cable.



NOTE :- * Deep Sea Electronics part number of BELDEN 9841 cable: 016-030



WARNING! 120Ω impedance cable must be used for the MultiSet Communications Link. Use of any other impedance cable may cause intermittent failures in communications, indicated by MSC alarms although the system may function normally during engine / panel testing.



NOTE 1: - The 120Ω terminator must be enabled on the first and last devices on the communications bus. See section header MSC Settings for further details.



NOTE 2: - It is important that the MultiSet Communications Link cable is run from one module to the next in a 'bus' fashion. 'Spurs' off this bus should be avoided where possible, but where a spur is unavoidable; its length should be kept less than 1m from the bus cable.

11.7 MSC ALARMS

Several alarms are provided to warn the operator of possible problems with the communication link between the gensets.

11.7.1 MSC ID ALARM

Each genset must have a unique MSC ID so that they can properly communicate. Should two or more sets have the same ID then one or more of the affected sets will declare "MSC ID ERROR" this will cause an electrical trip on the affected set. The correct ID must be set using the PC configuration software.

 **NOTE:** - To avoid possible problems with spare modules it is suggested that units are commissioned in the system starting with ID 1 and then 2,3... etc. Any modules used as spares should be configured as number 16,15... etc. These can then be added to the system without causing any conflicts with existing modules. Alternatively, use the PC configuration software to reconfigure the module to suit.

 **NOTE:-** DSE8710, DSE8610 and DSE7510 controllers "auto negotiate" their MSC ID alarms to ensure that conflicts will never occur.
5510 controllers version 5 and later also include this feature.

11.7.2 MSC DATA ERROR

When the sets are communicating on the MultiSet Communications link, should the data be corrupted the affected modules will display 'MSC DATA ERROR'. This will cause an electrical trip on the affected set.

 **CAUTION!** - Care should be taken to ensure that correct wiring is used between the modules, the MSC terminator is correctly enabled on only end units on the link and that maximum cable run distances are not exceeded. Should data error alarms be apparent, operation of the MultiSet system may not be possible.

11.7.3 MSC FAILURE

If the number of modules communicating on the Multiset communications link should fall, then an MSC failure alarm will occur. This can be configured to a 'warning' or 'electrical trip' type alarm. Should the number of modules on the communications link fall below the "Minimum modules on Multiset comms link" configurable setting, an additional alarm is triggered. This alarm can be disabled, or configured to generate a warning or electrical trip alarm.

If the number of modules communicating on the Multiset communications link should rise, then any existing 'MSC failure' warning alarm is cleared, and all communicating modules are automatically reconfigured to 'expect' the increased number of sets on the bus.

Additionally, one of the module's digital inputs can be configured so that the MSC failure alarm is disabled when the input is active. The module can be configured to alert / remind the user of this via an indication or warning alarm if required via the "Multiset comms alarm disabled action" setting.

 **NOTE:-** For details on the MSC failure alarm settings, you are referred to the appropriate PC configuration manual.

11.7.4 MSC TOO FEW SETS

This alarm activates if the number of sets on the MSC link is less than minimum number configured in the module.

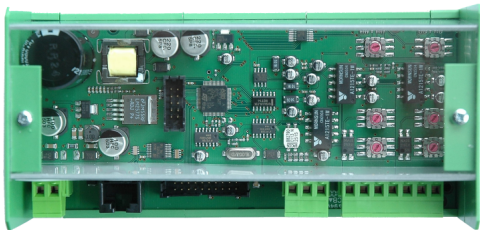
12 LOAD SHARE LINES

While the MSC link provides functions far in excess of what is possible using conventional load share line technology, occasions arise when it may be necessary to interface to an existing installation.

The DSE P123 module provides a method of connecting the DSE7510 and DSE5510 modules into the load share line based system.

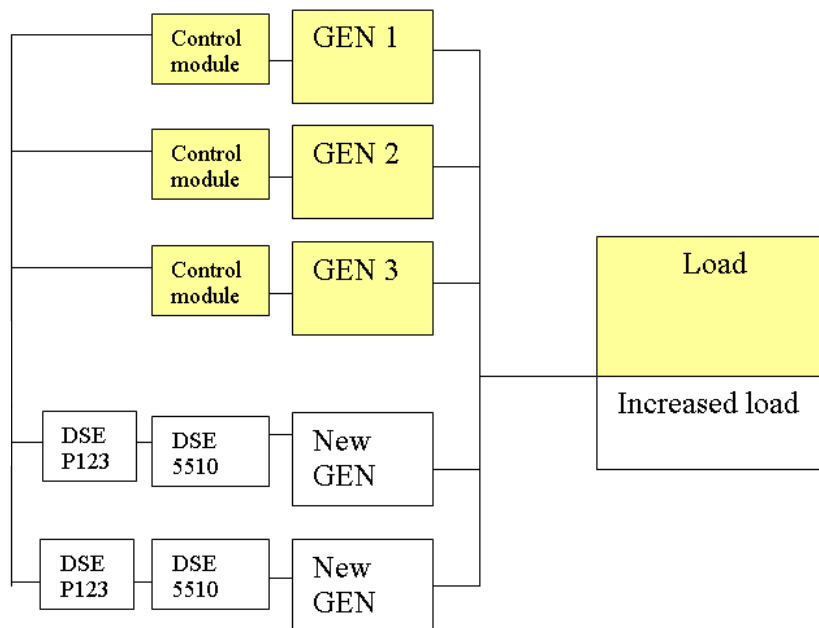
This mimics an additional set on the load share line system and will operate in both kW share and Kvar share modes (if supported by the installation).

The P123 is compatible with a range of different load share lines commonly found in the field; selection is via switches on the P123.



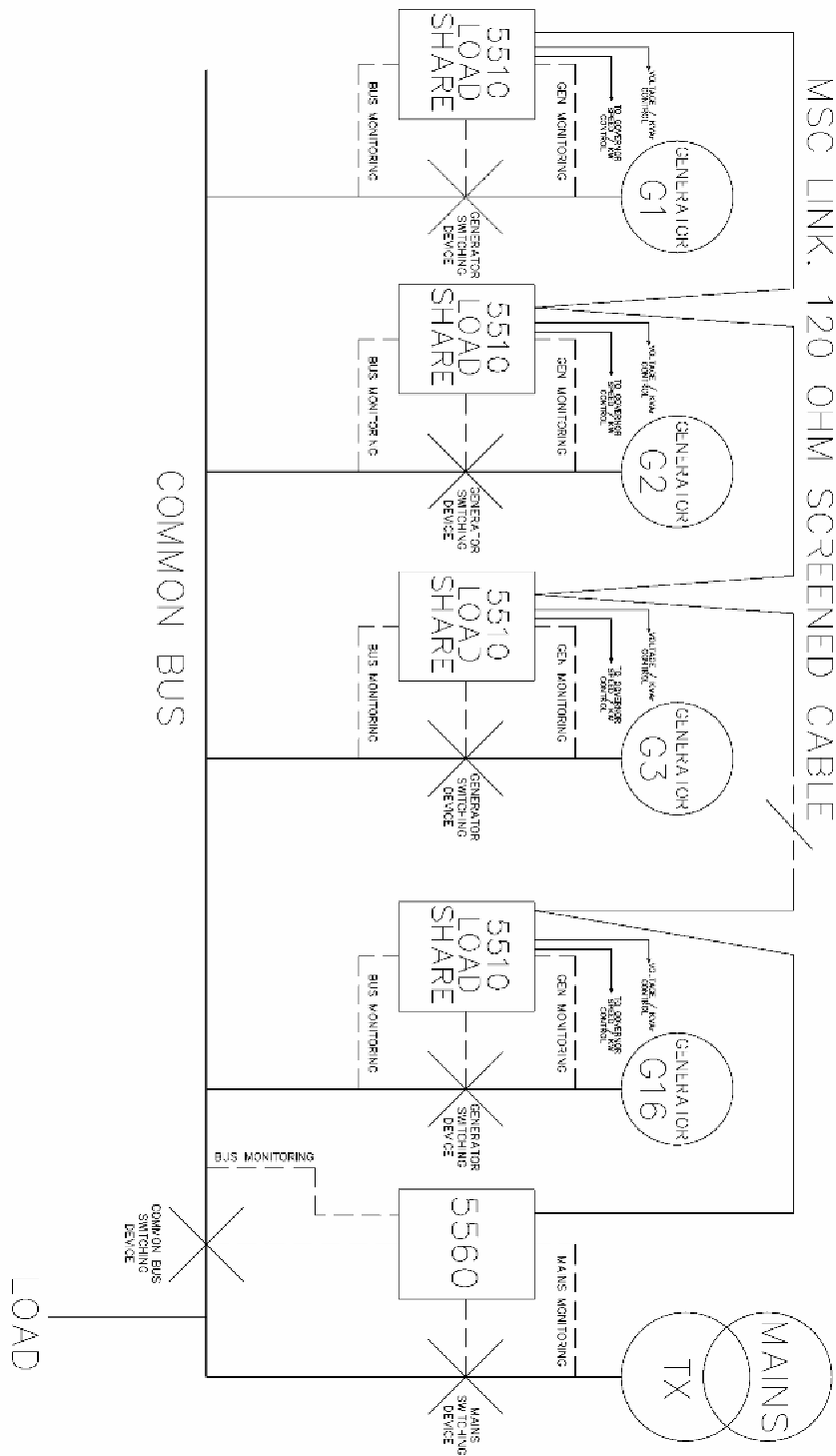
DSE123 is NOT compatible with DSE86xx or DSE87xx controllers.

12.1 TYPICAL P123 INSTALLATION



13 TYPICAL CONNECTIONS

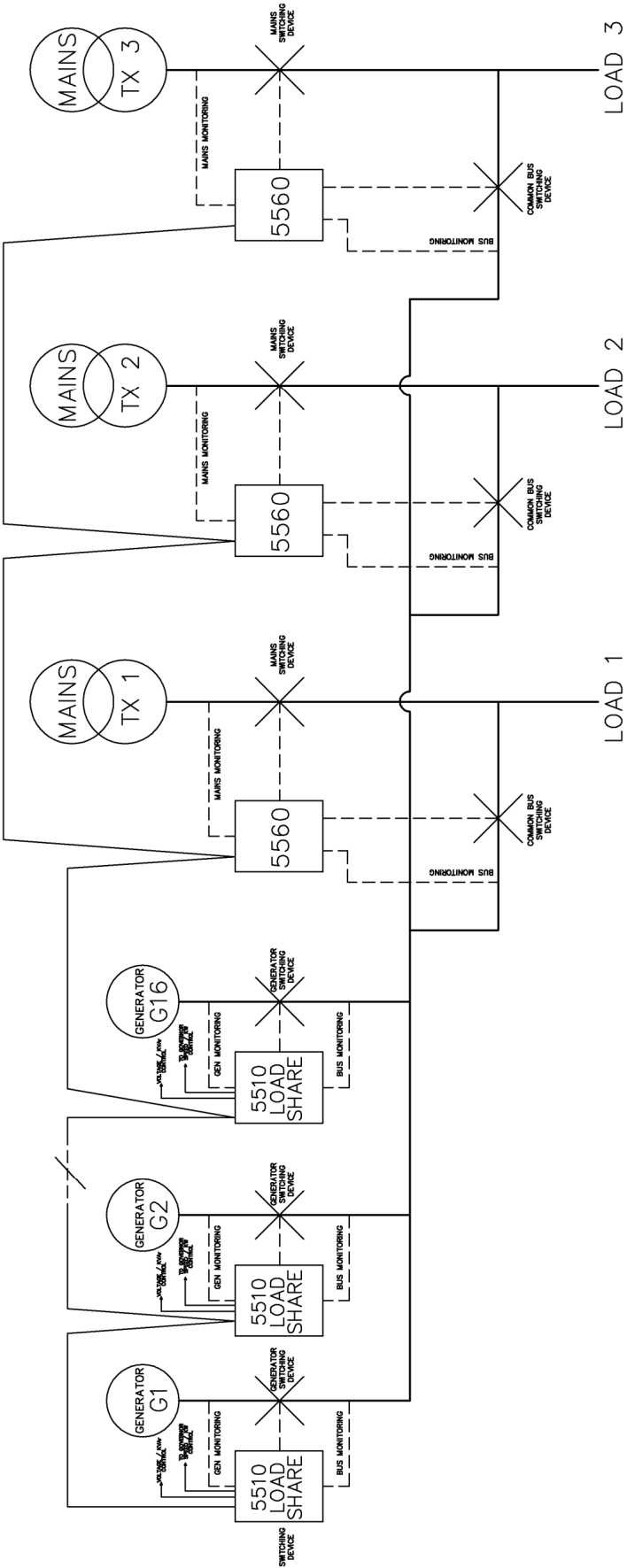
13.1.1 TYPICAL SINGLE LINE DIAGRAM OF MULTI SET MAINS FAIL



ALL BATTERY NEGATIVES MUST BE CONNECTED TOGETHER
FOR FURTHER DETAILS OF THE APPLICATION CONSULT THE GUIDE TO SYNCHRONISING AND LOAD SHARING
MAXIMUM TOTAL CABLE LENGTH OF THE MSC LINK IS 250 METERS, PROVIDED THE CORRECT CABLE IS USED.

13.1.2 SINGLE LINE DIAGRAM OF MULTI MAINS SYSTEM

MSC LINK. 120 OHM SCREENED CABLE



ALL BATTERY NEGATIVES MUST BE CONNECTED TOGETHER
FOR FURTHER DETAILS OF THE APPLICATION CONSULT THE GUIDE TO SYNCHRONISING AND LOAD SHARING
MAXIMUM TOTAL CABLE LENGTH OF THE MSC LINK IS 250 METERS, PROVIDED THE CORRECT CABLE IS USED.

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