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USER MANUAL

STC SERIES THYRISTOR STACKS FOR COMPLEX LOADS

For control of 3-phase loads in phase angle or soft start burst fire operating modes

Including appendix covering the STC2500 model



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CONTACTING US

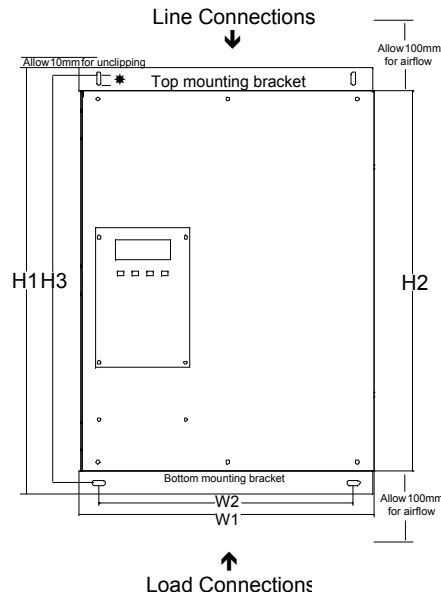
Please feel free to contact us if you require further information or advice on the application, installation or maintenance of these units.

If in doubt - ask!

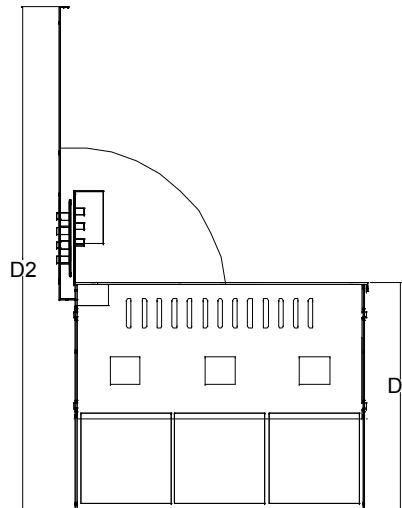
We can be contacted by telephone, e-mail, fax or letter. Contact information is on the front page of the manual. If you have a query regarding a specific unit, please let us know the model number and serial number of the unit, both of which are on the rating plate adjacent to the semiconductor fuses, when you contact us.

Figure 1 STC3000 Mounting Dimensions 80A to 800A

* 13mm
Correct position
for mounting
screw to allow
unclipping



Door fastening
wing nuts protrude
10mm this side



View from below.
(Door is hinged on
left hand side and
can open to 180°)

There are two model sizes covering 80A to 800A as shown below. All dimensions in mm. See appendix 2 for other models.

Current Rating	H1 Overall Height	H2 Height excluding mounting clips	H3 Vertical fixing centres	W1 Overall width	W2 Horizontal fixing centres	D1 Installed depth	D2 Depth with lid open 90°
80A to 200A	450	390	426	256	203	280	510
315A to 800A	578	500	543	389	336	305	670

DATA SHEET INFORMATION

Features

- Multiple feedback modes
- Comprehensive current, power and voltage limit facilities
- Current ratings from 80A to 1100A standard. Others available to order.
- Conservatively rated at 50°C (45°C 800A unit) ambient temperature
- Modbus® RTU or DeviceNet communications facility enable full remote monitoring and control
- Multiple I / O capability enable sophisticated control strategies
- True RMS measurement of load voltage and currents
- Can switch between phase angle and soft start burst fire control while operating
- 2 x 16 line LCD display for configuration and display of operating conditions
- Space saving design

General Description

This is a modern range of 3-phase thyristor stacks, operating in phase angle or soft start burst fire modes. They are specifically designed for control of AC heating loads in medium and high current applications for furnaces, ovens, dryers etc. These stacks are particularly useful where current limit is required (eg loads with low cold resistance), or for use with generator sets, or when feeding the primary of transformers. They are fitted with 2 analogue inputs and one analogue output, 4 isolated digital inputs, and 4 isolated digital outputs, 1 relay alarm output, and Modbus® RTU compatible or DeviceNet communications, providing a comprehensive systems capability.

Ordering Information

The stacks may be ordered using the order code shown below, or by description:-

Type	Current Rating	Voltage Rating	Driver Supply Voltage AC 50/60 Hz	Hardware Configuration Code	Devicenet comms if required
STC 3000					DeviceNet

80A, 125A, 160A, 200A, 250A, 315A, 400A, 600A, 800A, 1100A				
270V, 480V, 660V				
115V, 230V				
Standard, 6-wire open delta, 6 wire open delta/star				
DeviceNet communications if required				

The configuration code defines the hardware set up of the stack which we will deliver. Other details of the configuration may be set up as required by the user using a simple menu on the LCD display.

The standard configuration is for 3-wire star or delta loads (including 3-wire transformer loads), and 4-wire star loads.

The 6-wire open delta connection is for use with the stack wired in the delta loop, thus reducing the required current rating of the stack. It may be used with resistive loads or 3 single phase transformers which feed independent loads. It is not for use with delta / star connected transformer coupled loads, which require the 6-wire open delta / star configuration. This mode of operation requires an additional card to be fitted in the stack. Note that a special transformer is also required for this mode of operation, which should not be attempted with standard transformers

If DeviceNet communications are required this must be specified when the stack is ordered, as the control card build is different, different software is installed, and an extra interface card is fitted.

Summary of Facilities

LOAD CONFIGURATION

3 - wire star or delta, 4 - wire star, 6 - wire open delta.

FIRING MODES

The stacks operate in either phase angle mode, or soft start burst fire mode. Provision is made to switch between operating modes using a digital input. Current limit may be applied in either mode; in burst fire mode the stack will phase back if current limiting action is required. In burst fire mode the cycle time and the soft start / finish times may be independently set.

FEEDBACK MODES

In phase angle mode the stack may either be operated open loop, or closed loop with V , I , V^2 , I^2 , $V_{rms} \times I_{rms}$, or I^2 / V^2 transfer feedback. The I^2 / V^2 transfer is useful with loads which have a low cold resistance. The control signal initially controls the current fed to the load, until the voltage feedback signal becomes greater than the current feedback signal, when control is switched to voltage. Current limit action may also be applied.

In burst fire mode the stack operates open loop, with or without line voltage² feedforward compensation, as selected.

CONTROL AND LIMIT SETPOINTS

Control and limit setpoints may be provided as analogue inputs, settings on the LCD display, or via the communications link. There are two analogue inputs, so one may be assigned to control and one to a limit setpoint.

Setpoints available are; control, current limit, voltage limit, power limit. In theory all can be operational simultaneously.

Provision is made for limit setpoints to be activated / de-activated by means of digital inputs.

DIGITAL INPUTS

Six opto-isolated digital inputs are provided. These may be used as either sink or source in association with 24V DC plc / logic systems, or, using the energising supply provided, with volt free contacts.

They are assigned to; phase angle / burst fire select; 3 off limit enable; control setpoint local (keypad or comms) / remote; stack enable.

DIGITAL OUTPUTS

Two opto-isolated digital outputs are provided, which may be used as either sink or source in conjunction with 24V DC plc or relay logic.

They are allocated to: Any limit setpoint in control; Stack Enabled

In addition a relay output is available (volt free contacts), contacts rated up to 250V AC, which is allocated to an alarm condition.

ANALOGUE OUTPUT

One analogue output is provided, which may be used as a retransmission signal of; Load Voltage, Load current (average of 3 currents), Load Power.

Specifications

PHYSICAL

Stack Rating	Approximate dimensions	Approximate Weight
80A, 125A, 200A	390mm H x 256mm W x 280mm D	13KG
250A, 315A, 400A,	500mm H x 389mm W x 305mm D	27KG
600A, 800A	500mm H x 389mm W x 305mm D	34KG
1100A	500mm H X 757mm W x 350mm D	65 KG

ENVIRONMENTAL

Ambient Operating Temperature	0-50°C (0-45°C - 800A unit)
Storage Temperature	-25 to +70°C
Relative Humidity	0-95% non condensing
Pollution (IEC 664)	Degree 2 (Only non conductive pollution is allowed. Temporary condensation may occur, but not normally while equipment is operating).
Elevation	Derate current rating 1% per 100 metres above 200 metres

ELECTRICAL

Rated Supply Voltage (Load)	270V (170 to 300), 480V (300 to 530), 660V (415 to 700)*
Rated Current	As ordered. Rated current is specified at 45 / 50°C ambient temperature
Supply Frequency	50Hz or 60Hz +/-8%
Rated Impulse Withstand Voltage (IEC 664)	4KV
Auxiliary Supply for control electronics	115 or 230V +10% -15%, 50/60 Hz. 80A unit 40VA; 125, 200A units and fans 90VA; 315, 400A, 600A units 115VA; 800A unit 190VA.

CONTROL SIGNAL INPUTS AND OUTPUTS

Analogue input control signals	0-5V, 1-5V, 0-20mA, 4-20mA, 0-10V, 2-10V (mA signals use 250Ω burden resistor)
Analogue output signal	0-5V, 0-10V, link selectable.
Digital Inputs	Optoisolated from main control board, isolation voltage 1,500V RMS, but not from each other. Logic high level 5V to 30V. Logic low level 1V. Alternative contact closure input, using on-board isolated supply.
Digital Outputs	Optocoupled transistor outputs, sink or source, rated 24V DC, 50mA.
Alarm Relay Output	Volt free contacts, rated 250V AC, 30V DC, 2A

LED INDICATORS AND DISPLAY

A green LED indicates that the stack is enabled. A red LED indicates an alarm condition. A 2 line x 16 character LCD display and 4 buttons are used for configuration and calibration, and in use are used for entry of setpoints, and reading of line and load voltages, load currents etc.

COMMUNICATIONS

The stacks are provided with a galvanically isolated communications port which can be link configured as either RS422 (separate tx and rx twisted pairs) or RS485 (single twisted pair). The protocol emulated is a subset of Modbus® RTU. This facility enables most parameters (eg setpoints, voltages, currents, digital I/O) to be read, and setpoints to be written. Analogue parameters are stored as 16bit binary values, representing the parameter in engineering units, multiplied by 10 (eg a current of 96.5A would be stored as 965 converted to 16 bit binary). Baud Rates available are 4,800; 9,600; 19,200; Parity odd; even or none.

At extra cost the stack may be fitted with an additional card offering communications to the DeviceNet fieldbus standard.

Notes

The 80A unit is convection cooled. All other units are force cooled. An auxiliary power supply of either 115 or 230V +10%, -15%, 50/60 Hz. is required on all units to power the control electronics, and fans when fitted. All units are fitted with snubber capacitors and MOV transient over voltage protection.

* 660V units. Note that impulse withstand voltage is restricted to 4kV. Consult us.

Compliance With Standards

Electrical

The stacks are designed to meet the requirements of international standards and are CE marked in compliance with the European Low Voltage Directive.

The following standards have been applied in whole or in part in the design of these units: EN 60947-1, EN61010-1, EN50178

Electromagnetic Compatibility

The control circuits of the unit meet or exceed the requirements of EN 61000-6-2 and EN 50 081 part 2 (immunity and emissions for industrial environment). Systems compliance with EN 50 081 is not possible in phase angle mode, without the use of external filters.

SAFETY INFORMATION

These thyristor stacks are intended for installation inside an enclosure which requires the use of a tool to gain access.

These thyristor stacks must be earthed. The earthing arrangements must be able to carry the fault current associated with a short circuit of the main load circuit to the metalwork of the stack, until the protection device opens.

Thyristor stacks must never be used as a means of supply isolation, as even in the 'off' state lethal leakage currents will flow. An independent means of isolation, complying with local standards must always be fitted.

The hinged door and polycarbonate top and bottom covers provide protection against accidental contact with live parts, but this does not mean that such parts are not accessible. The door and covers must never be opened or removed unless the main and control supplies have been isolated elsewhere. Busbars and circuitry on the printed circuit boards carry the full line voltage.

Maintenance and installation work on these units should only be carried out by suitably qualified and trained personnel who have read and are familiar with the contents of this manual. Account must also be taken of local regulations.

Additional information is provided under 'Installation – General Requirements'.

CHANGING THE FUSES AND TABLE OF SEMICONDUCTOR FUSE TYPES

Checking or changing of any fuse must not be attempted unless both main and driver supplies are isolated. To attempt to change them without isolating both supplies is extremely dangerous, and may also cause damage to the stack.

Control Card Fuse

The control card is fitted with a single subminiature European TR5 fuse which protects the primary of the mains transformer (see figure 5 for position). The fuse is antisurge (type T), rating 500mA for 115V supply, 200mA for 230V supply. The secondary of the transformer is protected by an electronic fuse which resets automatically when power is removed.

Semiconductor Fuses

The semiconductor fuses listed in the table overleaf may be used. Consult us before using other fuse types. One fuse is required per phase. The fuses used on the 80A to 400A units are fitted with blade contacts; those in the 600 and 800A units have end contacts.

BLADE CONTACT TYPES

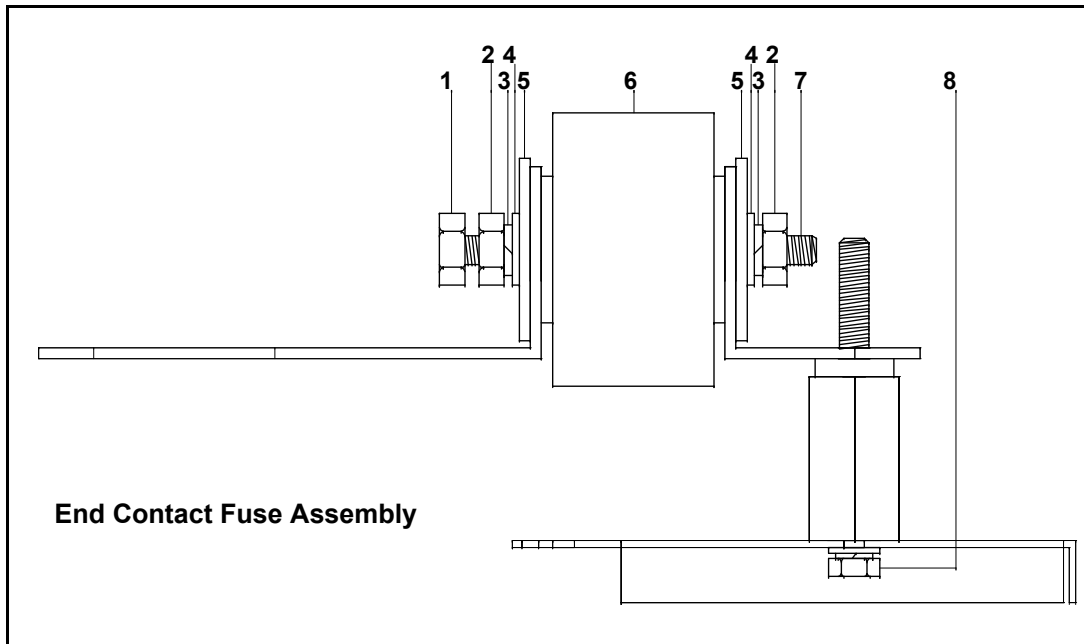
The upper fuse support pillars are adjustable in slotted holes to cater for the different pitch of alternative fuses. If necessary slacken the hex head fixing screws on the reverse side of the mounting plate (see (8) in the drawing for end contact types), and adjust the pillar as required, then re-tighten.

Note that a serrated lock washer is fitted behind the fuse on the upper studs. It is most important that this is not omitted, otherwise excessive torque may be transmitted to the stud when the fuse retaining nuts are tightened. The recommended tightening torque for these nuts is 10Nm on 80 to 250A units, 15Nm on 315A and 400A units.

END CONTACT TYPES

It is imperative when loosening or tightening the nuts which secure these fuses that a counterbalancing torque is applied to the screw on which the nut is tightened. Failure to do so could result in damage to the busbars, thyristor module and fuse. A hex headed screw (1) is fitted inboard, and a hex socket screw (7) nearest the line connections.

Remove the old fuse by slackening the retaining nuts (2) and pulling the fuse (6) forward through the slots in the busbar. Ensure that a counterbalancing torque is applied as above. Remove the socket / hex head set screws from the fuse and screw them hand tight into the new fuse (with nuts and washers fitted as before), while holding the fuse in the hand. Slacken off the M8 hex head screws (8) which hold the line cable support pillars to the support plate, to allow the line busbar to tighten up correctly against the new fuse, which may be of slightly different thickness. Slide the fuse into the slots in the busbars. Ensure that the 50mm load spreading washers (5) are fitted, and that they are seated flat against the busbars (not held off by the bend radius in the busbar) and the busbars are seated properly against the fuse. Ensure the fuse is inserted to the same depth in each busbar. Retighten the fuse nuts, applying a counterbalancing torque - recommended torque 25Nm. Retighten the cable support pillar screws (8), first ensuring that the pillars are square against the busbar.



	1 Hex head screw	2 Nuts	3 Spring Washer	4 Plain Washer	5 Pressure Washer	7 Socket head screw
600A	M10x30mm	M10	M10	M10	50mm OD / 12.5mm I/D	M10x35mm
800A, 1100A	M12x35mm	M12	M12	Not fitted	50mm OD / 12.5mm I/D	M12x35mm

M = ISO Metric Coarse.

Stack Current Rating	Nominal Fuse Current Rating	Fuse I ² t Rating (A ² s) @ 660V	Fuse Type BS88 Fixing Centres	Alternative fuse type DIN 43 653/80/000 (80mm fixing centres, offset tab)
80A Ferraz Bussman	110A	6,800	E330100 170M1485	170M1318 (125A)
125A Ferraz Bussman	160A	16,000	F330055 170M1469	170M1319
160A Ferraz Bussman	250A	52,000	H330057 170M1487	170M1321
200A Ferraz Bussman	315A 300A	82,000	J330058 170M1488	170M1322 (315A)
250A Ferraz Bussman	315A	82,000	J330058	170M1322
		Fuse I ² t Rating (10 ³ A ² s) @ 660V	Fuse Type (DIN 43 653 80mm fixing centres)	Alternative Fuse Type (N. American fixing centres)
315A Ferraz Bussman	450A	140 120	C 300 014 170M4013	X 300 032 170M3620
400A Ferraz Bussman	550A	280 230	E 300 016 170M4015	Z 300 034 170M3622
			End Contact types	
600A Ferraz Bussman	900A	900 840	Q300 072 170M5415	
800A Ferraz Bussman	1100A	1,260 1,300	C300 083 170M6415	
1100A Ferraz	1500A		Y300585	

INSTALLATION AND WIRING

General Requirements

The following notes are a guide to ensuring sound system design, and compliance with the requirements of the European Low Voltage Directive and other international standards.

The stacks should be installed in a cabinet requiring a tool to gain access, and access should be restricted to suitably trained and qualified personnel. Provision should be made to exclude conductive pollution (eg graphite or foundry dust) from the cabinet, and to avoid condensation.

Caledon thyristor stacks are designed with an impulse withstand voltage of 4kV. This meets the requirements of IEC and European standards for installation category 3, and supply voltage (line to earth) up to 300V (AC RMS). This corresponds to 520V line to line (480V nominal) on most distribution systems, in which the supply transformer is star connected with earthed star point. This does not preclude the use of the stacks in higher voltage systems (provided the thyristor devices are suitably rated), but precautions may be necessary (eg surge arrestors) to limit the expected impulse voltage level, if systems compliance with the above standards is required.

All stacks in the STC range incorporate integral semiconductor fuses. These are intended to provide short circuit protection for the thyristor devices, by limiting the peak half cycle surge current and total energy let through. They only provide limited protection against long term overload. The stack ratings are co-ordinated with standard HBC fuse values, and the supply cables should be protected with gL fuses or circuit breakers of current rating the same as, or lower than the stack. All the stacks with fan cooling also incorporate automatically resetting thermal cut outs, which monitor the temperature of the heatsink, and ensure that it does not rise to an unsafe level.

The stacks must be fitted with a protective earth conductor, and the earth connection must be capable of carrying the prospective fault current for the main load circuit until the protective fuse blows. The main reason for this is to protect against short circuit to ground which might occur in one of the semiconductor modules, should the internal structure rupture under severe fault conditions. Provided the correct semiconductor fuses are fitted, which limit the maximum energy let-through under short circuit conditions, a short cable of 25mm² cross section connecting between the stack earth stud and the chassis plate will provide an adequate local earth. Care must be taken to ensure that the panel in which the stack is installed is adequately earthed, with an earth loop impedance less than 0.03 Ω (400V, 800A system), and taking account of local regulations. Note that rfi filter capacitors fitted to the stack, together with leakage via the power modules can result in earth leakage currents in normal operation of the order of 5mA.

The stacks are rated for a maximum ambient operating temperature of 50°C (45°C for 800A unit). This refers to the ambient air temperature entering the heatsinks at the base of the stack. The design of an installation must however take into account the ratings of cables and other switchgear within the cabinet. Elevated temperatures also shorten the life of some electronic components, notably electrolytic capacitors, which dry out. A major cause of elevated temperatures in a cabinet containing thyristor stacks is the power dissipated by the thyristor devices, which may be approximated in watts as 1.5 x (RMS current) x (Number of controlled lines). The exhaust air temperature from the stack will be higher than ambient by up to 20°C. It is not good practice to mount other items of control gear directly in the exhaust airflow. In particular the current carrying capability of fuses or circuit breakers will be significantly reduced if this is done. A tidy solution is to mount circuit breakers or fuses supplying the stack on a sub-chassis mounted forward from the main chassis on which the stack is mounted. The exhaust air then passes behind these components. Thyristor stacks should not be mounted one above the other, as this will significantly derate the upper unit, which, for rating purposes will be operating in an ambient equal to the exhaust air temperature of the lower unit. Heat from the thyristors, together with that dissipated by the semiconductor fuses will also raise the temperature of the stack busbars to which outgoing cables are connected, and high temperature cables should be used. The cross-section of the cables and their ventilation will influence the temperature of the connection studs, and the guide in the wiring section of this manual shows recommended cross sections.

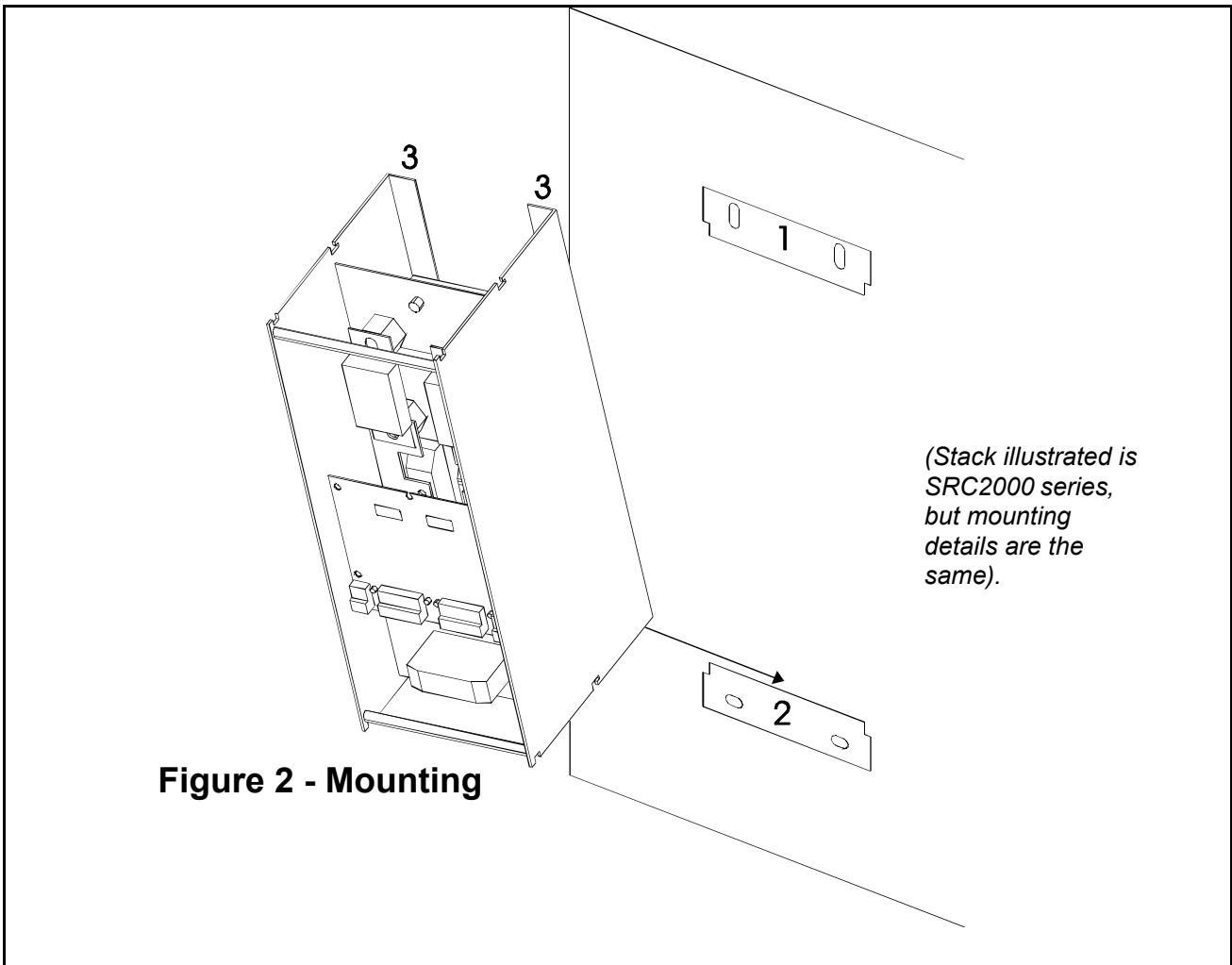
Consideration must be given to fault conditions. In particular a short circuited thyristor could result in loss of control of the load current. If this could cause a dangerous temperature to arise in the controlled load, then an independent means of monitoring and switching off the current should be provided. This could take the form of an independent over-temperature controller switching a contactor or under voltage release on a circuit breaker fitted in the main supply lines (see figure 3 for example). Contacts should be arranged to de-energise in the alarm (over temperature) state. European standard EN 60519-2 Safety in electroheat installations, part 2: Particular requirements for resistance heating equipment, para 13.3 requires independent protection of electronic heating controllers and frequently operated heating control contactors, where temperature rise in the load could otherwise be excessive under fault conditions.

Independent provision for electrical isolation of the power and control circuits must be provided.

Mounting

The stack must be mounted vertically, with the fan at the bottom of the unit. Allow a minimum of 100mm above and below the stack body to allow free airflow. Do not mount stacks one above the other. The stacks may be mounted closely side by side in multi-zone applications, but care must be taken to ensure that the door can be opened. We recommend a minimum gap between units of 50mm.

The mounting arrangement for units up to 800A is shown in figure 2. For the 1100A unit see appendix 2. Screw the upper and lower mounting brackets (1 and 2) to the mounting plate, but do not fully tighten. For units up to 200A use M6 x 16mm screws or similar (suitable holes should be drilled and tapped in the mounting plate). For units 315A to 800A use M8 screws. We recommend tapping the mounting plate and screwing in hex head screws from the rear to form captive studs, and using nuts at the front to hold the mounting plates. Fixing dimensions are shown in figure 1. Hook the stack over the lower mounting bracket, and raise the upper mounting bracket to the limit allowed by the slotted holes so that the stack may be installed against the mounting plate and the bracket hooked down over it. Tighten up first the top bracket, and then the lower bracket.



Typical Wiring Schematics

Figure 3 shows an outline typical wiring schematic, and figure 4 shows skeleton outlines of various load connections. Fuses and provision for isolation, furnace over temperature etc must be fitted as described in 'General Considerations' above.

Figure 3

Typical wiring schematic with stack feeding a delta / star transformer coupled load. The load on the transformer secondary is delta connected.

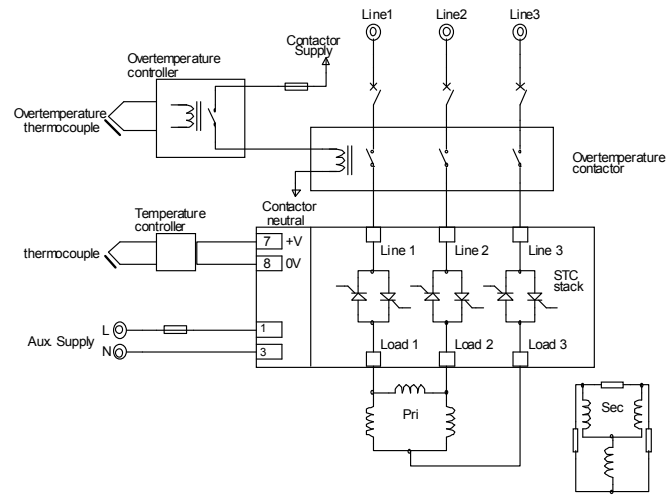
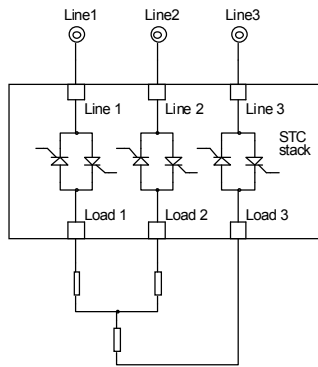
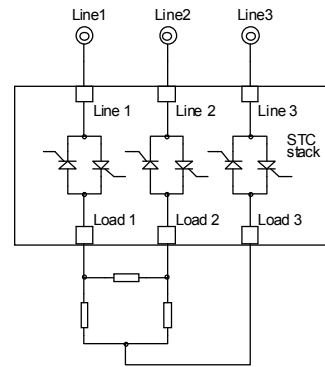


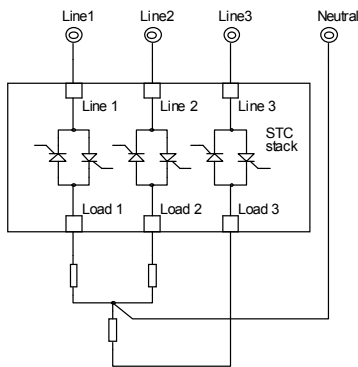
Figure 4 - Skeleton load connection diagrams



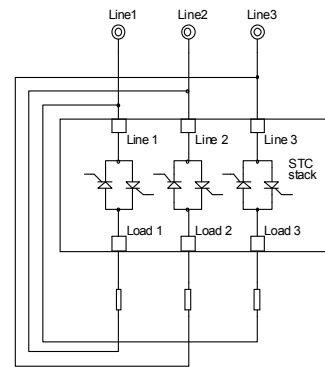
i - 3 wire star connected load



ii - 3 wire delta connected load



iii- 4 wire star connected load



iv - 6 wire open delta connected load (with stack wired in the delta loop). It is most important that the rotation of the connections; ie load 1 to line 2 etc. should be as shown, and not reversed.

Recommended Power Cable Sizes

The following is a guide only, as installation conditions will vary. A maximum control cabinet temperature of 45°C has been assumed, with cables routed in free air in the immediate vicinity of the stack, and passing into trunking in groups of three. The cable protective fuse or circuit breaker rating has been assumed to be equal to the stack current rating. For units rated up to 200A a cable with a maximum operating temperature of 85/90°C has been assumed. Above 200A high temperature cable should be used, with an operating temperature of 120°C. Suitable types are Brand Rex cross linked polyolefin (POLYRAD) or coil leads type 5 to BS 7655 with silicone rubber insulation. The 600A and 800A units have been designed for use with two cables connected in parallel.

STACK RATING	CABLE X SECTION
80A	25mm ²
125A	50mm ²
160A	70mm ²
200A	120mm ²
250A	120mm ²
315A	150mm ²
400A	150mm ²
600A	2 x 150mm ²
800A	2 x 150mm ²
1100A	2 x 185mm ²

Power Cable Wiring

Use the guide in the previous paragraph when determining cable type and cross section. Cables should be connected using heavy duty tube type ring crimp terminals. The stud diameter is 8mm on the 80A to 200A units, 10mm on the 315A and 400A units, 12mm on the 600A and 800A units. Do not forget to feed the line and load cables through the holes in the polycarbonate covers before attaching to the terminals!

A protective earth connection of suitable cross section should be made to the stud at the top of the unit.

More information is provided under 'Installation - General Requirements'.

Note that all studs are fitted with a plain and spring washer. The recommended tightening torques are 10Nm on M8 studs and 15Nm on M10 and M12 studs.

Control Cable Wiring

It is not specifically necessary to use screened cable for the wiring of control circuits to meet the emc immunity level specified in EN 61000-6-2. We recommend that good wiring practice be followed within the control panel in which the stack is installed, taking care to avoid running signal wiring parallel to high current or switching circuits as far as is reasonably practical. If signals are sourced from outside the panel we recommend that screened cable be used outside the panel, and the screen earthed at the point of entry to the panel. This is most conveniently undertaken using special glands, but if pigtailed are used these should be earthed to the metalwork as directly as possible. If screened cable is used between the entry to the panel and the stack, then the screen should be earthed to the metalwork near the stack. Incorrect earthing of screened cables can result in worse performance than using non-screened cables.

Control Signal Connections

These connections are made direct to the printed circuit board connectors on the control card which is fitted in the lid of the stack. The connectors are suitable for cable up to 1.5mm² cross section. Cables are fed via the slot in the plastic cover at the bottom of the stack. Note that all connectors are unpluggable for ease of maintenance.

Terminal Function List

The following table shows the terminal functions, with brief explanations.

Number	Function	Comment	
Control card and fan power supply			
1	Supply Live	Either 115V or 230V, as defined on the stack rating plate. The voltage rating cannot be changed without changing the fans. This supply does not need to be phase related to the 3-phase supply. The supply cable should be protected with a circuit breaker or fuse, not greater than 6A. The control transformer is protected by an on board fuse. The fans are impedance protected.	
2	No connection		
3	Supply Neutral		
Alarm Relay Connections			
4	Normally open	Open in the de-energised or alarm state.	The alarm relay contacts should not be wired in the coil circuit of a contactor wired in the 3-phase supply to the stack, as the stack is in alarm when it loses the 3-phase supply, and this will prevent the supply from energising.
5	Normally closed	Closed in the de-energised or alarm state. Alarm relay contacts are volt free, and suitable for wiring into circuits energised with up to 250V AC 30V DC, 2A.	
6	Common		
Analogue inputs Analogue inputs and outputs share a common 0V rail, which is isolated from the digital I/O.			
7	Analogue input 1 +	Remote Control setpoint.	Wire a 250 ohm burden resistor across the input terminals for mA inputs. The input can be set as 0-5V or 1-5V in the configuration menu, and converted to 0-10V or 2-10V by fitting jumpers (see figure 5)
8	Analogue input 1 - (0V)		
9	Analogue input 2 +	Limit setpoint if configured	
10	Analogue input 2 - (0V)		
11	+5V	A supply that can be used in conjunction with a potentiometer to feed the analogue inputs for manual setting if wished. (Configure the input as 0-5V)	
Continued on next page			

Number	Function	Comment
Digital inputs - <i>With the exception of the enable input, the function below may be controlled by comms if the inputs are left unconnected. Digital inputs are isolated from the analogue inputs and output, and may be activated by volt free contacts or 24V DC plc transistor outputs. It is possible if desired for some inputs to be link activated, and others by plc outputs.</i>		
12	Common for inputs activated by links	Digital inputs can be activated by linking to this terminal, or by closing a volt free contact between this terminal and the required input. (This terminal is at +5V with respect to terminal 19).
13	Digital Input 1 - Control setpoint local / remote	If set, control setpoint is from analogue input 1. If not set control setpoint is from keypad or communications.
14	Digital input 2 - Activate current limit	If set, current limit is active. If not set current limit is not active, but will still operate if the load attempts to draw a current greater than the rating of the stack.
15	Digital input 3 - Activate voltage limit	If set, voltage limit is active. If not set voltage limit is not active.
16	Digital input 4 - Activate power limit	If set, power limit is active. If not set power limit is not active.
17	Digital input 5 - Select firing mode.	Soft start burst fire if set. Phase angle if not set.
18	Digital input 6 - Enable Stack	The stack will not supply power to the load unless this input is set. This input must be hard wired even when control of the stack is by means of the communications.
19	Common for inputs energised by plc transistor outputs	Connect to plc +24V for use with plc pull down outputs. Connect to plc 0V for use with plc pull up outputs. (Inputs can be activated by a minimum of 5V, and are de-activated at less than 1V)
Analogue Output		
20	Analogue output +	The analogue output can retransmit one of 3 parameters, set in the configuration menu. The standard output signal is 0-5V. It may be converted to 0-10V by fitting jumper 4 (see figure 5).
21	Analogue output - (0V)	
Digital Outputs		
22	Digital output 1 emitter	Any limit setpoint is in control. Stack Enabled Output Digital outputs are volt free NPN transistors, which may be wired as either pull up or pull down in logic systems up to 24V. They may also be used to drive DC relays up to 50mA and 24V. The outputs are protected by 30V zener diodes, and suppressor diodes on relays driven by the outputs are not required. The digital outputs are electrically isolated from the analogue I/O. Although they are not electrically connected to the digital inputs, the isolation voltage between digital inputs and outputs is not guaranteed.
23	Digital output 1 collector	
24	Digital output 2 emitter	
25	Digital output 2 collector	
Modbus Communications (Not applicable if DeviceNet card is fitted)		
26	0V screen	Communications may be either 2 wire (common Rx and Tx) or 4 wire (separate Rx and Tx), as selected by jumper 1 (1B = 4 wire, 1A = 2 wire). If using 2 wires, connect to terminals 29 and 30. The cable screen should always be connected to terminal 26. Terminating resistors (240 ohm) may be connected by fitting jumpers 8 (Receive) and 9 (Transmit). Screened twisted pair cable of 100 or 110ohm characteristic impedance should be used. If the DeviceNet communications card is fitted these terminals are not active.
27	Receive A	
28	Receive B	
29	Transmit A	
30	Transmit B	
DeviceNet card		
1	Supply -	The Anybus DeviceNet card is the small daughter board fitted in front of the control card. The connector provides the standard DeviceNet interface. 24V power must be supplied to this connector for the DeviceNet port to operate. The DeviceNet interface is galvanically isolated from all other I/O. Cables must conform to the DeviceNet standard.
2	CAN L	
3	Screen	
4	CAN H	
5	Supply +	

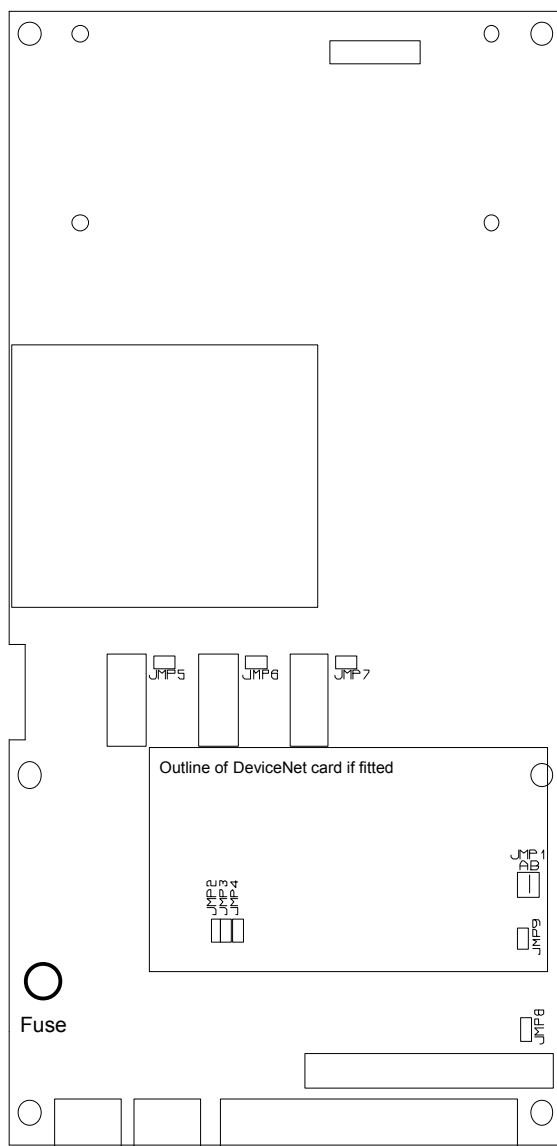


Figure 5 - Jumper positions on control card

If the DeviceNet daughter board is fitted, this will have to be unscrewed to gain access to jumpers 2, 3, 4, 1, 9 which are underneath it.

JMP 5, 6, 7 Do not alter the settings of these jumpers.

JMP2 When fitted converts analogue input 1 from 0-5V or 1-5V to 0-10V or 2-10V

JMP3 When fitted converts analogue input 2 from 0-5V or 1-5V to 0-10V or 2-10V

JMP4 When fitted converts analogue output from 0-5V to 0-10V

JMP1 Fit in position A for 2 wire RS485 (Modbus) communications; fit in position B for 4 wire (separate Rx and Tx)

JMP8 Fit to connect 240Ω terminating resistor across RS485 Receive lines

JMP9 Fit to connect 240Ω terminating resistor across RS485 Transmit lines

COMMISSIONING AND CONFIGURATION

General Considerations

The following points must be considered when commissioning the stack.

- 1 Is the hardware configuration compatible with the configuration set in the configuration menu, and the chosen load connection?
- 2 Is the stack configured for the correct line voltage, and the required operating mode?
- 3 Is the control circuit power supply the correct voltage -115V or 230V? This is ultimately determined by the voltage rating of the fans fitted.
- 4 Is the hardware I/O wired as required? At the very least the 'enable' input must be activated for the stack to operate.
- 5 Is the stack to be operated with communications? If so note the specific points in the section headed 'Considerations when using comms'.

Navigating the Display

The display has two lines; the upper line generally has an instruction or label, and the lower line a value. This value may be read only (eg line voltage), or adjustable (eg a setpoint). A map of the configuration menu is laid out in the table below. The menu tree can be considered as a number of layers with several parameters on each layer. To scroll round the parameters on a layer (vertical columns in the table) use the scroll (⤵) button. To change to the next layer (move across columns) use the enter (↵) button. The ↵ symbol appears on screens where it is possible to change layers. To return to a previous layer scroll to the 'previous layer' screen and press enter. To change adjustable parameters use the up (⬆) or down (⬇) button to change to the desired value. Holding down ↵ while ⬆ or ⬇ are pressed speeds up the rate of change of the value.

Configuration Display Menus

The fundamental operating parameters for the stack are defined using the display in configuration mode, and stored in EEPROM. To enter configuration mode all 4 buttons must be pressed simultaneously on first energising the control supply to the stack, while the 'L1 L3 PL TE MODE' screen is displayed (the screen displayed on power up), and before the stack enables for the first time (green LED illuminates). Normally this will allow approximately 5 seconds in which to press the buttons, but if this is not enough the hardware 'enable' input can be disconnected, or the 3-phase supply left un-energised, to allow as much time as required. Once the desired parameters have been set, there is a choice of 'no save and exit' or 'save and exit' which return the stack to normal operating mode. The table below shows the available options, which are described in detail after the table cross referenced by the reference number.

Ref No	Level 1 ⤵	↵	Level 2 ⤵	Δ∇
1	Load Type			3-wire; 4-wire star; delta loop; delta loop / star
2	Phase angle	↵		
3			Feedback Mode	Open Loop; Voltage; Voltage ² ; Current; Current ² ; V _{RMS} X I _{RMS} ; I ² / V ² transfer
4			Response Speed 1	1-80 (seconds)
5			Response Speed 2	1-80 (seconds)
6	SS Burst Fire	↵		
7			Feedback Mode	Open Loop; Line Voltage Compensation
8			Cycle Time @ 50Hz	1s to 60s @ 50Hz
9			Ramp up time	1-80 cycles @ 50Hz
10			Response Speed 2	1-80 (seconds) Same parameter as for phase angle
11	Comms Config	↵		
12			Modbus unit ID	1-127
13			Baud Rate	4,800; 9,600; 19,200
14			Parity	None; Even; Odd
15			Comms mode	Read only; Read / Write

Continued on next page

16	Analogue I/O ↵		
17		AN1 Range	0-5V; 1-5V
18		AN2 Range	0-5V; 1-5V
19		AN I/P2 PA Funct	None; Voltage Limit; Current Limit; Power Limit
20		AN I/P2 BF Funct	None; Current Limit; Power Limit
21		AN O/P Funct	Load Voltage; Load Current; Load Power
22	Set V & I Spans ↵		
23		Set V Span	0 - stack maximum voltage
24		Set I Span	0 - stack rated current
25	Save and Exit ↵	(Return to Operating mode)	
26	No Save and Exit ↵	(Return to Operating mode)	

		↵	↻	↵	↻	Δ∇
27	Calibration ↵					
28		Maximum Voltage	Read only - consult us if these values require changing.			
29		Maximum Current				
30		Current rating				
31		Adjust scaling ↵				
32		Cal Line Volts *				0.8000 to 1.2000
33		Cal Load Volts *				0.8000 to 1.2000
34		Calibrate I1 *				0.8000 to 1.2000
35		Calibrate I2 *				0.8000 to 1.2000
36		Calibrate I3 **				0.8000 to 1.2000
37						Return to top level

* Press ↵ to move to next line. **Press ↵ to return to top level

The following notes provide more information on the menu functions where appropriate. They are cross referenced by the reference number from the table above

1 Load Type

There are a number of different load configurations, and for correct firing and feedback operation these must be set to match the connected load. The delta loop configurations also require hardware changes to be made on the stack snubber boards otherwise the stack will not read the correct load voltage.

3-wire

This is the most common connection, without neutral. The load may be star or delta connected, and if transformer coupled the secondary of the transformer may be connected either star or delta. It is essential for one of either the primary or secondary of a transformer to be delta connected, to avoid unbalance caused by triplen harmonics. The normal connection is delta / star.

4-wire star

A star connected load with the star point connected to neutral. Note that with this connection, even with a balanced load, heavy neutral currents can flow in phase angle operation, particularly if the stack is operating in current limit, when the neutral current can be nearly twice the line current.

True delta loop - also check hardware configuration.

The stack is wired in the delta loop, thus reducing the required current rating by a factor of $\sqrt{3}$. This mode is for use with three single phase loads; ie 3 resistive loads or 3 single phase transformers. It is most important that the rotation of the load connections should be as shown in Figure 4 (iv).

Delta loop / star - also check hardware configuration

This mode is for the specific case of a transformer coupled load, with the stack wired in the delta loop of the primary, and the secondary star connected with either a 3-wire star or delta connected load. This configuration requires special firing pulses and specially connected voltage feedback. Note that this mode of operation causes high reflected voltages across the thyristors (Peak = 1.5x peak line voltage), and between the stack load connections and ground (Peak = 1.8x peak line to ground voltage). A special transformer is also required, otherwise there is very likely to be excessive leakage of magnetic flux and unacceptable heating of the transformer frame and casing.

2 Phase angle

Enter the setup parameters for phase angle operating mode

3 Feedback Mode

When the stack is operating in phase angle mode the controlled variable may be selected from this list. Open loop controls the firing angle in proportion to the control signal. I²/V² transfer compares the normalised feedback signals for I² and V², and controls whichever is the greater to the setpoint.

If it is proposed to switch between phase angle and burst fire operation while running it is a good idea to choose V feedback in phase angle mode, and line voltage compensated operation in burst fire mode. This will ensure that the power supplied to the load remains approximately constant during the switch over.

If the controlled variable is volts or amps the setpoint is also set in volts or amps. For other controlled variables the setpoint is set as a percentage of maximum. The maximum values are determined from the values for 'V span' and 'I span' set under 'Set V and I spans'. These are also the values used to normalise the feedback for I²/V² transfer.

V_{RMS} X I_{RMS} is an approximation to providing 'true power' feedback. The actual formulae used depend on the load configuration, as follows:-

3-wire star or 4 wire star $\frac{V_{LOAD} \times (I_1 + I_2 + I_3)}{\sqrt{3}}$ where V_{LOAD} is measured between load terminal 2 and load terminal 3, not load terminal to star point.

6-wire (stack in delta loop) $V_{LOAD} \times (I_1 + I_2 + I_3)$ where V_{LOAD} is measured load terminal 2 to line terminal 3.

For 4-wire star and true delta loop load configurations the calculated power will be accurate at all firing angles. For other load configurations, if the load is unbalanced there will be an inaccuracy, normally less than 10%. The calculation takes account of the power factor degradation caused by the chopping action of the thyristors, but not of any angle of lead or lag caused by the load.

4 Response Speed 1 (Range 1-80 seconds, typical value 5 seconds)

This parameter sets the speed at which the stack phases up and down under integral action. The value should be set empirically to optimise the speed of response without resulting in oscillatory control, which will occur if it is set too fast. When operating in a feedback mode involving current you should make the time constant cautiously long, as the loop gain is effectively increased when operating into (for example) a low cold resistance load.

5 Response Speed 2 (Range 1-80 seconds, typical value 20 seconds)

This parameter is as parameter 4, but operates when the stack is in current limit. If the stack is to be used with loads having a low cold resistance, such as Molybdenum disilicide it may be necessary to set this value to 10x the value set in (4) to ensure stability. This parameter is also available in the SS Burst Fire menu.

6 SS Burst Fire

Enter the setup parameters for soft start burst fire operating mode.

7 Feedback Mode

Open loop means that the ratio of on to off time is defined entirely by the setpoint, and is independent of variations in load or in supply voltage. With line voltage compensation the setpoint signal is modified by the factor

$$\frac{(\text{Span Voltage})^2}{(\text{Line Voltage})^2} \quad (\text{see 22 and 23})$$

This keeps the power supplied to the load reasonably independent of supply voltage variations, but means that if the supply voltage is high the stack will not turn on continuously. (Also see 3 above).

8 Cycle Time @ 50Hz (Range 1s to 60s, typical value 15s on transformer load, 5s on resistive load)

Sets the approximate period in seconds that the stack takes for a complete on + off cycle. The period remains constant for duty cycles between 10% and 90%, but is then lengthened to accommodate minimum on and off times, set at 10% of the cycle time. The minimum duty cycle (below which the stack is off) is 1%. The control algorithm counts 3-phase supply cycles, so the period will be faster on 60Hz supplies.

9 Ramp up time (Range 1-80, calibrated approximately in supply cycles @ 50Hz), typical value 10.

Sets the time the soft start (and end) of a burst takes to ramp up (and down). Note that care must be taken not to set this time too long in comparison with the duty cycle, as this will prevent the stack from turning on fully. The fastest time available is in practice limited to approximately 7 cycles.

10 Response Speed 2 (Range 1-80 seconds, typical value 20.

Sets the response speed when the stack goes into current limit in either phase angle mode or ss burst fire mode. The value set here should be much higher than the normal response speed, to ensure stable operation into low resistance loads (This is the same parameter as in (5) above).

11 Comms Config

Note that if DeviceNet communications are fitted, Modbus unit ID, baud rate and parity are not available on the menu. The DeviceNet baud rate and Mac ID must be set on the DIP switch on the DeviceNet card.

15 Comms mode

The setting here determines whether communications are 'read only' (user interrogates the stack) or read/write (user can also send setpoints etc to the stack). If the communications are read only they are not monitored by the stack, and will not cause the stack to shut down if communication with the user is lost. If the communications are read/write, then the stack will alarm and disable if communication with the user is lost, and can only be re-enabled by re-establishing communication, or by re-configuring the stack to read only.

16 Analogue I/O

Configures the analogue I/O. Analogue input 1 is always assigned to the control setpoint, but analogue input 2 can be assigned to one of the three limit setpoints, and different limits may be chosen for phase angle operation and burst fire operation. If 'None' is chosen then the limit setpoints will be set on the buttons or by the communications. The control setpoint source may be switched between analogue input 1 or the buttons / communications by digital input 5.

17 AN1 Range

The input can be ranged to accept 0-5V or 1-5V. A link on the board (see figure 5) can be fitted to halve the gain of the input amplifier, ranging the input to 0-10V or 2-10V. For mA signals use a 250 ohm burden resistor across the input terminals in conjunction with 0-5V or 1-5V

18 AN2 Range

As AN1 range.

19, 20 AN I/P 2 Funct

Analogue input 2 may be set to control one of the limit setpoints if desired. It is possible to control a different limit in phase angle mode from burst fire mode, or only to control a limit in one of the two modes. When the limit is not configured for this input (ie 'none' is chosen) it is available as a local setpoint.

21 AN O/P Funct

The analogue output may be set to retransmit load voltage, current or power. The standard output is 0-5V, which may be changed to 0-10V by fitting jumper 4 on the control card (see figure 5). The output is scaled so that 5V (or 10V) represents 1.2x Span, span defined in 22 to 24 below. This enables the output to cope with an overload without saturating.

22 Set V & I Spans

The values set here determine the range over which the stack setpoints will operate. If operating with 'power' feedback, the span is calculated using the formulae in 3 above, and the values set here.

23 Set V Span

The value set here will normally be the nominal supply voltage on which the stack is to operate. Note however that if this is done, and the actual supply voltage is high, it will not be possible to make the stack turn fully on, as with a setpoint of 100% the stack will control the output to the span. This will be true for Voltage, or Voltage² control in phase angle mode, and control with line voltage compensation in burst fire mode. In power control the effect will also depend on the current span.

24 Set I Span

The value set here will normally be slightly higher than the maximum current drawn by the load.

25 Save and Exit (Return to Operating mode)

When this option is chosen all values in the configuration are saved. Until 'Save and Exit' is performed any changes which have been made have not been saved. If power is removed before saving them they will be lost. After saving the stack reverts to normal operation.

26 No Save and Exit (Return to Operating mode)

Returns to normal operation without saving any configuration changes made, which are lost.

27 Calibration

The calibration procedure allows the calibration to be checked or adjusted with little danger of completely mis-adjusting the values. The values set in 28, 29 and 30 are read only. Consult us if you think they are incorrect or need adjusting. After making changes to the calibration the 'Save and Exit' routine must be performed to save them. On software versions S135E1 up to issue R3, and S136E1 up to issue R6, only the span can be calibrated. On software issues above these the zero can also be adjusted.

28 Maximum Voltage

This value is read only. It is factory set to match the hardware, and represents the maximum voltage which the A/D converter on the control board can accept.

29 Maximum Current

This value is read only. It is factory set to match the hardware, and represents the maximum current which the A/D converter on the control board can accept.

30 Current rating

This value is read only. It is factory set to match the hardware, and represents the maximum current which the stack is designed to conduct. Current limit action will occur if the load attempts to draw a current greater than this value.

31 Adjust scaling

The values set in 28 and 29 nominally calibrate the stack, but do not take account of component tolerances. The 'adjust scaling' screens (32 to 36) enable a scaling factor to be adjusted while observing the measured parameter on the upper line of the display. On software versions S135E1 version R4 and above, and S136E1 version R7 and above, the zero offset may also be adjusted on these screens. This should be done before adjusting the scaling factor. With no voltage or current applied, a small zero offset may be observed. Pressing the \cup button will remove this offset. It may be pressed more than once, until the best results are obtained. When this has been done a suitable signal may be applied and the scaling factor adjusted as described below.

The nominal value of the scaling factor is 1.000 with provision to vary it from 0.800 to 1.200. Press \downarrow after entering the required value, to move to the next parameter. Increasing the scaling factor increases the value recorded by the stack. Because the stack is not operating when in configuration mode, it is not simple for the user to check the calibration while viewing the screen, because apart from the line voltage it is not possible to apply the required voltage or current to the stack. However, when the stack is operating normally, a note can be taken of the recorded values on the normal operating display, and compared with the reading on the user's reference meter. The required adjustment to the scaling factor can be calculated and the scaling factor adjusted subsequently if desired. Note that the measurements made by the stack are true RMS, and any meter used for calibration purposes must be true RMS reading, otherwise there will be serious errors when measuring phase angle controlled waveforms. At the factory the voltage calibration is performed with the stack off load, and corresponding line and load terminals shorted together. Current calibration is performed from the secondary of the current transformer only (ie any inaccuracy in the current transformer is not compensated).

Considerations When Using Communications / Communications Parameters

There are two modes in which communications can be used with the stack (selected in the 'Comms Config' menu in configuration):-

- 1 Read Only - in which the user can read values of parameters in the stack, but cannot change any values.
- 2 Read and Write - in which the user can both read values of parameters in the stack and also change certain values, eg setpoints or digital I/O.

If 'Read Only' mode is chosen the user can access the readable (production) data registers as desired. This has no effect on the operation of the stack, which must be controlled by hard wired signals, eg setpoints or digital I/O. If using DeviceNet communications the stack node must be configured for 19 16-bit registers. All the data listed in the table of registers is made available, and this cannot be altered. In the event of a failure within the stack of communication between the control processor and the DeviceNet card, the values of all registers will be set to zero. Otherwise communications are not monitored by the stack.

If Read and Write mode is chosen then two sets of registers become available to the user - read only (production) and write only (consumption) (These may also be read if using Modbus communications, but the values in them will simply be those written to them by the user). If using DeviceNet communications the stack node must be configured to have 19 read (production) registers and 6 write (consumption) registers. The read only registers behave as above. The write only registers give the user control over the following items:-

All the digital inputs except the enable input. The default condition for these is low or inactive. They may be set high by the hard wired inputs, in which case the communications cannot set them low, or if the hardwired inputs are left disconnected (low) the communications is free to set them high or low as required. A hardware enable (digital input 6, terminal 18) is always required.

All the 'local' setpoints; ie those otherwise set using the buttons on the stack user interface. When communications are set to 'Read/Write' the facility to use the buttons to set local setpoints is disabled. This means that the user must send values to all these setpoints if he wishes to use them. It is not possible to set

some of the setpoints via communications and some using the buttons. Setpoints configured to be set via analogue inputs cannot be set via communications (but they can be read).

A 'comms' enable bit. This bit must be set to 1 (in addition to wiring the hardware enable) for the stack to operate.

A 'comms established' bit. This bit must be set to 1, otherwise the stack will alarm and shut down. This bit should be permanently set at 1. If communications is lost it will be set to zero as described below, causing a stack alarm.

With Modbus communications the stack continuously checks to see if the stack is being polled, and if it does not receive a poll for approximately 10 seconds all writable registers will be set to zero. With DeviceNet communications, if the fieldbus network stops communicating all writable registers will be set to zero. This action is a safety measure which switches the stack off in the event of failure of the communications.

Numerical parameters are presented as 16 bit binary values representing the parameter value in engineering units multiplied by 10.

The tables below detail the registers. All registers are 16 bit.

Read Only (Production) Registers			
<i>The Modbus address is given. On DeviceNet communications the registers appear in the order below</i>			
Ref No	Modbus Address (Hex)	Name	Additional Information
1	01	Status Register 1	Stack operating status Bit 0 Line 1 present Bit 1 Line 3 present Bit 2 Phase lock achieved Bit 3 Heatsink temperature OK Bit 4 Phase angle / burst fire mode (burst fire when set) Bit 5 Stack enabled Bit 6 Alarm (Software versions S135E1 issue R2 and S136E1 issue R5 and above) Bit 8 Current limit active (stack is being controlled to the limit setpoint) Bit 9 Voltage limit active Bit 10 Power limit active Bits 7 and 11-15 not used
<i>Remote Setpoints can be read here. They cannot be written by communications.</i>			
2	02	Working Setpoint	The setpoint which is controlling the stack (either local or remote), except when a limit setpoint is in control. Value in units associated with the controlled parameter (% , volts, amps)
3	03	Remote setpoint 1	Analogue input 1, control setpoint, value in units associated with the controlled parameter (% , volts, amps) .
4	04	Remote setpoint 2	Limit setpoint if configured. Value in units associated with configured parameter (% , volts, amps) . Set to zero if 'none' configured.
5	05	Line Voltage	In volts
6	06	Load Voltage	In volts
7	07	Load 1 Current	In amps
8	08	Load 2 Current	In amps
9	09	Load 3 Current	In amps
In burst fire mode, when the stack is cycling, the values of the on-state load voltage and currents are transmitted continuously, updated at the end of each on period. When the stack is conducting continuously they are updated continuously, and when the stack is off they are reset to zero.			
10	0A	Average Current	Average of the three load currents in amps
11	0B	Load power (kW)	(Calculated using the formulae in ref 3 under 'Configuration')
12	0C	Load Power (%)	As percentage of span
13	0D	Diagnostic Register	Not implemented
<i>Local setpoints read here are as set by the buttons if communications write is not configured, or echo back the values written into the write registers in the next table if communications write is configured. If too large a value is written to the 'write' register, the value echoed back here will be limited to the valid range).</i>			
14	0E	Local Phase angle control setpoint	In units associated with the control parameter (% , volts, amps)
Continued on next page			

Ref No	Modbus Address (Hex)	Name	Additional Information
15	0F	Local SS Burst Fire Control Setpoint	In %
16	10	Local current limit setpoint	In amps
17	11	Local power limit setpoint	In %
18	12	Local voltage limit setpoint	In volts
19	13	Status Register 2	Digital I/O and enable status Bit 0 Digital input 1 Control setpoint local if not set, remote if set Bit 1 Digital input 2 Current limit enable when set Bit 2 Digital input 3 Voltage limit enable when set Bit 3 Digital input 4 Power limit enable when set Bit 4 Digital input 5 Phase angle operation if not set, ss burst fire if set Bit 5 Comms enable bit Bit 6 Comms established bit (only used when stack is in read/write mode) Bit 7 Not used Bit 8 Digital Input 6 Hardware enable Bit 9 Digital output 1 - Any limit active See 'Operating Status Indication' for definition of these output states. Bit 10 Digital output 2 - Stack Enabled Bits 11 to 15 not used

Write (Consumption) Registers

The Modbus address is given. On DeviceNet communications the registers appear in the order below.

Ref No	Modbus Address Hex	Name	Additional Information
Local setpoints Local control setpoints are those set via the buttons on the stack in the 'local setpoints' menu, or via the comms. Remote setpoints are those set via an analogue input, and they cannot be written via the comms. Local control setpoints can be written to by the comms when comms write is enabled, and cannot then be set using the buttons. The value set in these registers should be the required value multiplied by 10, and expressed in 16 bit binary. This effectively allows one decimal place to be sent; eg setpoint 39.5A, send 395 expressed in binary.			
1	14	Local phase angle control setpoint	The control setpoint is the normal setpoint which operates when a limit setpoint is not active. It is set in the units applicable to the type of feedback mode set in configuration (% , volts, amps) .
2	15	Local SS Burst Fire Control Setpoint	Set In %
3	16	Local current limit setpoint	Set in amps (0-I _{SPAN})
4	17	Local power limit setpoint	Set in %
5	18	Local voltage limit setpoint	Set in volts (0-V _{SPAN})
6	19 (Coil / bit address 0-6)	Status Register 2	Digital Input and 'comms stack enable bit' This register enables digital inputs to be set via comms. The bit assignments are as below. For the stack to operate the hardware enable input must be high, and when comms write mode is enabled bit 5 and bit 6 of this register must be set. Bit 0 Digital input 1 Control setpoint local if not set, remote if set Bit 1 Digital input 2 Current limit enable when set Bit 2 Digital input 3 Voltage limit enable when set Bit 3 Digital input 4 Power limit enable when set Bit 4 Digital input 5 Phase angle operation if not set, ss burst fire if set Bit 5 Comms 'stack enable' Bit 6 Comms established bit (must be set by user, otherwise stack will alarm) Bits 7-15 are not used and values written to these bits are discarded.

DIP SWITCH SETTINGS AND LEDS ON THE DEVICENET CARD (WHEN FITTED)

The DIP switch on the DeviceNet card enables setting of the baud rate and MAC ID. Settings for baud rate etc on the display configuration menu refer only to the Modbus communications, and are not available when the DeviceNet card is fitted. The Mode setting in the configuration menu (Read only or read/write) is applicable to both Modbus and DeviceNet.

The DIP switch settings are only read at switch on of the stack control card supply.

1,2 Set the baud rate
00 = 125k; 01 = 250k; 10 = 500k; (11 reserved)

3-8 Module address (MAC ID); (coded in binary, switch 3 = MSB, 8 = LSB) Addresses 0-63 may be set.

There are 4 LEDs on the DeviceNet card. The two left hand LEDs are unused. The right hand LEDs are 'Network Status' and 'Module Status'. Indications are as follows:-

Module Status	Steady off	No network power
	Steady red	Unrecoverable fault
	Steady green	Device operational
	Flashing red	Minor fault
Network Status	Steady off	Not powered / Not on line
	Steady green	Link OK on line. Connected
	Steady red	Critical link failure
	Flashing green	On line not connected
	Flashing red	Connection time out

MODBUS RTU COMMANDS

The Modbus RTU communications accept the following Modbus commands:-

- 0x03 Read Holding Registers Applicable to the whole address range.
- 0x10 Force Multiple Registers Applicable to the Write address range above
- 0x05 Force Single Coil (Bit) Applicable to Status register 2, bits 0-6

OPERATION AND OPERATING USER INTERFACE

Covers

For safety reasons the stack should not be operated with the door open. Additionally, the fans direct a proportion of their airflow over the control card and semiconductor fuses, and this cooling action, particularly of the fuses, will be impaired if the door is open.

Operating Status Indication

In normal operation the operational status of the stack can be determined with the use of the LEDs and LCD display on the fascia.

For the stack to fire (supply current to the load) the red Alarm LED must be off and the green Enable LED must be on.

The alarm LED (and output) will come on if any of the following occur :-

- Any of the 3-phase supply phases is missing.
- The stack loses phase lock.
- The heatsink temperature is too high.
- If the communications mode is read/write and the communication link has failed.

The enable LED (and output) will only come on 3 seconds after the following conditions are met:-

- All 3 supply phases are present.
- The stack has achieved phase lock.
- The heatsink is below its maximum limit temperature.
- The hardware enable (digital input) is set.
- The communications enable bit is set (only required if the communications is read/write).

If the alarm LED is on, or the stack fails to enable, the cause can be determined by looking at the status of the flags on the first two screens of the LCD display. The following sections describe the use of the display and the meaning of the flags.

When the stack is operating the display can also be used to read values of the currents, voltages and power it is

controlling, and (if appropriate to the application) to adjust operating and limit setpoints.

Navigating the Display

The display has two lines; the upper line generally has an instruction or label, and the lower line a value. This value may be read only (eg line voltage), or adjustable (eg a setpoint). A map of the operating display menu is laid out in the table below. There are a number of parameters on each layer, and two layers. To scroll round the parameters on a layer (vertical columns in the tables) use the scroll (⤵) button. To change to the next layer (move across columns) use the enter (↵) button. To return to a previous layer scroll to the 'previous layer' screen and press enter. To change adjustable parameters use the up (⬆) or down (⬇) button to change to the desired value. Holding down ↵ while ⬆ or ⬇ are pressed speeds up the rate of change of the value.

Operating Display Menus

The operating menu appears as in the table below, and further explanations are provided after the table where appropriate, cross referenced to the reference number:-

Ref No	Level 1					Level 2		Δ∇
	⤵					⤵		
1	L1	L3	PL	TE	MODE			Read Only
	*	*	*	*	BF / PA			
2	C	CE	HE	IL	VL	WL		
	*	*	*	*	*	*		
3	Control Setpoint							
4	Local S/Ps							
5						PA Control S/P	Set in units defined for control parameter (% , volts, amps)	
6						BF Control S/P	0-100%	
7						Current Limit S/P	0-Stack current span	
8						Power Limit S/P	0-100%	
9						Voltage Limit S/P	0-Stack voltage span	
10	Line Voltage							Read Only
11	Load Voltage							
12	Line 1 Current							
13	Line 2 Current							
14	Line 3 Current							
15	Average I Value							
16	Load Power							
17	Conduction Angle							

1 L1 L3 PL TE MODE

This screen displays a number of flags, and there must be asterisks under all the flag labels (indicating that the flag is set) before the stack will fire. The flags are as follows:-

- L1 Line voltage is present between line 1 and line 2
- L3 Line voltage is present between line 3 and line 2
- PL The stack has synchronised to the 3-phase supply (phase locked)
- TE The stack heatsink temperature is not over its allowable limit.

The operating MODE can be either burst fire (BF) or phase angle (PA) as indicated.

2 C CE HE IL VL WL

This screen displays flags as follows (the flag is set when an asterisk appears below its label):-

- C Communications are established (Only in Read/Write mode) (Modbus or DeviceNet)
- CE The 'comms enable' bit is set. This is required when communications are in Read/Write mode before the stack will fire.
- HE The hardware enable input is set. This is required before the stack will fire.
- IL The stack is operating in current limit.
- VL The stack is operating in voltage limit
- WL The stack is operating in power limit

3 Control Setpoint

This is the setpoint to which the stack is controlling the load (unless a limit setpoint has taken control as indicated

on screen 2. It may have come from analogue input 1 or a local setpoint set by the buttons or by the communications.

4 Local S/Ps

This screen gives access to local control and limit setpoints. These values are normally read only, but can be set by the buttons, or, if the communications are in Read/Write mode, by communications. If the communications are not in Read/Write mode the local setpoints may be 'unprotected' so that they can be adjusted by the buttons, by pressing all four buttons together while the PA control setpoint is being displayed. After leaving the 'local setpoints' layer of the menu the values will again become write protected. If the communications are in Read/Write mode, local setpoints can only be set using communications.

The limit setpoints can only become active if the associated digital input or communications bit has been set high. Note however that current limit will always operate if the load attempts to draw a current greater than the rated current of the stack.

New values take effect immediately they are entered. They are stored in the stack RAM, and saved to EEPROM when the 'Local setpoints' menu layer is exited, or when power is removed from the stack control board. If the menu is left on the 'Local Setpoints' layer and the processor resets for some reason (an operating error) before the control card next powers down, any changes to the local setpoints will be lost, and previous values restored from the EEPROM.

5 PA Control S/P

This setpoint operates when the stack is in phase angle mode and local setpoint. It may be set in different engineering units from the burst fire setpoint (which is always set in %), depending on what load parameter the stack is set to control in phase angle mode.

6 BF Control S/P

This setpoint operates when the stack is in burst fire mode and local setpoint. It is set in Percent of maximum.

7 Current Limit S/P

The current limit setpoint operates on the greatest of the 3 measured line currents, and phases back the stack to limit this to the setpoint. In burst fire mode the stack will limit the conduction angle in the 'on' burst if the current limit would otherwise be exceeded.

8 Power Limit S/P

When the stack is operating in phase angle mode power limit limits the measured power supplied to the load as calculated using the formulae below:-

3-wire or 4 wire star	$\frac{V_{LOAD} \times (I_1 + I_2 + I_3)}{\sqrt{3}}$	where V_{LOAD} is measured load terminal 2 to load terminal 3, not load terminal to star point.
6-wire (stack in delta loop)	$V_{LOAD} \times (I_1 + I_2 + I_3)$	where V_{LOAD} is measured load terminal 2 to line terminal 3.

When the stack is operating in burst fire mode the 'power' limit is applied to the setpoint, and effectively limits the maximum 'on' time. This does not take account of the current being drawn by the load.

9 Voltage Limit S/P

The voltage limit setpoint does not operate when the stack is in burst fire mode.

10 Line Voltage

The true RMS voltage measured between line terminals 1 and 2. Note that if one of the line supply fuses blows, this voltage may still read line volts/ $\sqrt{3}$. This is caused by the class Y (line to earth) capacitors fitted on each line of the stack for rfi suppression purposes resulting in a measurement of the voltage between line and earth.

11 Load Voltage

When the stack is configured for 3-wire or 4-wire star load types this is the true RMS voltage measured between load terminal 2 and load terminal 3. Note that for 4-wire star loads and balanced 3-wire star loads this is $\sqrt{3}$ x the voltage between load terminal and star point.

When the stack is configured for delta loop load type, this is the true RMS voltage measured between load terminal 2 and line terminal 3.

When the stack is configured for delta loop / star a special measurement is taken, which is proportional to the voltage seen on the transformer secondary.

12 Load 1 Current

The true RMS current flowing out of load terminal 1. Note that when the stack is in the delta loop, the line current

from the supply will be $\sqrt{3}$ x the value displayed here.

13 Load 2 Current

The true RMS current flowing out of load terminal 2. Note that when the stack is in the delta loop, the line current from the supply will be $\sqrt{3}$ x the value displayed here

14 Load 3 Current

The true RMS current flowing out of load terminal 3. Note that when the stack is in the delta loop, the line current from the supply will be $\sqrt{3}$ x the value displayed here

15 Average I Value

The average of the three currents above.

16 Load Power

Load power as calculated from the formulae listed in (8) above. In burst fire mode the load voltage and currents are measured when the stack is conducting fully; power is calculated by entering these values in the formula, and the result is multiplied by the ratio of on time to (on + off) time. The value obtained in this way may not correspond exactly with the setpoint, as in burst fire mode the stack does not operate with closed loop control.

17 Conduction Angle

Shows the conduction angle at which the stack is operating. For 3-wire and delta loop/star operation the nominal range required is 0-150°, but, other than in open loop phase angle mode the stack is allowed to advance the angle to 170°, which compensates for unbalanced loads. For 4-wire and true delta loop (effectively 3 single phase loads) the range is 0-180°.

CONTROL PARAMETERS AND THEIR UNITS

The following is a summary of the units used for the various setpoints and measured values.

Phase Angle Operation

SETPOINTS

The setpoint is set in percent, except when the feedback mode (controlled parameter) is voltage or current, in which case the setpoint is set in volts and amps respectively.

For Open Loop Control

100% corresponds to the maximum conduction angle, 150° for 3-wire operation, 180° for 4-wire operation or 6-wire delta loop operation.

For V² Control

100% corresponds to $(V_{SPAN})^2$. Therefore Setpoint (%) = $\frac{(V_{LOAD})^2 \times 100}{(V_{SPAN})^2}$

Where V_{LOAD} is measured load terminal 2 to load terminal 3 for 3-wire and 4 wire star connected loads (not load terminal to star point), and is measured load terminal 2 to line terminal 3 when the stack is in the delta loop.

For I² Control

100% corresponds to $(I_{SPAN})^2$. Therefore Setpoint (%) = $\frac{(I_{LOAD})^2 \times 100}{(I_{SPAN})^2}$ (where I_{LOAD} is the average of the 3 load currents)

Note that when the stack is in the delta loop the supply current will be $\sqrt{3}$ x the current measured here.

For V_{RMS} x I_{RMS} Control ('Power' Control)

3-wire or 4-wire star load

100% corresponds to $V_{SPAN} \times \sqrt{3}(I_{SPAN})$

And Setpoint (%) = $\frac{V_{LOAD} \times (I_1 + I_2 + I_3)}{\sqrt{3} \times V_{SPAN} \times \sqrt{3}(I_{SPAN})} \times 100$

where V_{LOAD} is measured load terminal 2 to load terminal 3, not load terminal to star point.

6-wire (stack in delta loop)

100% corresponds to $V_{SPAN} \times 3(I_{SPAN})$

$$\text{And Setpoint (\%)} = \frac{V_{LOAD} \times (I_1 + I_2 + I_3) \times 100}{V_{SPAN} \times 3(I_{SPAN})} \quad \text{where } V_{LOAD} \text{ is measured load terminal 2 to line terminal 3.}$$

MEASURED POWER

The measured power expressed as a percentage uses the formulae defined above. Power is also displayed in kW, calculated using the following formulae, and dividing by 1000:-

$$\text{3-wire or 4 wire star} \quad \frac{V_{LOAD} \times (I_1 + I_2 + I_3)}{\sqrt{3}} \quad \text{where } V_{LOAD} \text{ is measured load terminal 2 to load terminal 3, not load terminal to star point.}$$

$$\text{6-wire (stack in delta loop)} \quad V_{LOAD} \times (I_1 + I_2 + I_3) \quad \text{where } V_{LOAD} \text{ is measured load terminal 2 to line terminal 3.}$$

Soft Start Burst Fire Operation

SETPOINTS

The setpoint is expressed in percent.

For Open Loop Operation

$$\text{Setpoint (\%)} = \frac{(\text{On Time}) \times 100}{(\text{On Time} + \text{Off Time})}$$

For operation with Line Voltage Compensation

$$\text{Setpoint (\%)} = \frac{(\text{On Time}) \times 100}{(\text{On Time} + \text{Off Time})} \times \frac{(V_{LINE})^2}{(V_{SPAN})^2}$$

Power Limit. With ss burst fire operation the power limit acts on the setpoint, and not the measured power. It is effectively a second setpoint defined as above, and the stack will control to whichever is the lower of the control setpoint or the limit setpoint.

MEASURED POWER

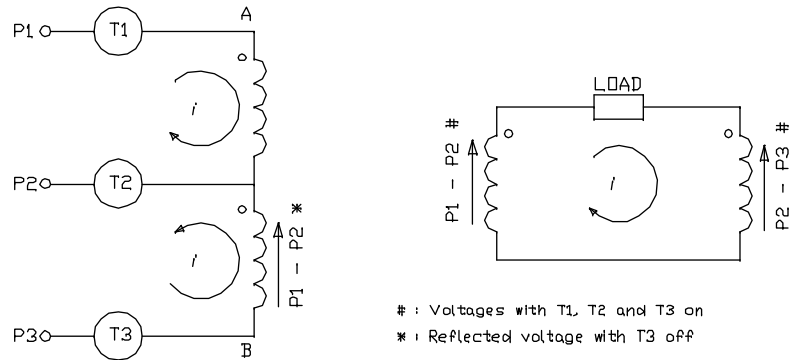
The measured power is defined by measuring the currents and voltage when the stack is conducting during an 'on' period, calculating the power using the same formulae as for phase angle operation, and multiplying the result by the known ratio of (on time) / (on time + off time). The measured power expressed in percent will not necessarily equal the setpoint value, as the setpoint does not take account of the actual value of the load current with either feedback mode. (As an extreme example, if there is no load on the stack the control setpoint could be any value, and the measured power would always be zero).

APPENDIX 1 STC2500

The following notes apply only to the STC2500 range, and describe the differences between these units and the STC3000.

Application and Wiring

The STC2500 series stacks are intended for 2 line control of a transformer coupled load with open V primary, and secondaries connected to supply a single phase load (see figure). This is the only load type for which they are suitable, and the configuration menu has no provision for other load types.



The outer limbs of the stack (T1 and T3) are controlled, and should be connected to the open ends of the V primary of the transformer. The centre limb of the stack is fitted with a straight through busbar, and should be connected to the centre limb of the transformer. The centre limb is intended to carry twice the current flowing in the outer limbs. The stack is rated for the outer limb current.

The centre limb connection to the stack is used to monitor the limb current, to monitor line and load voltages, and to determine phase rotation.

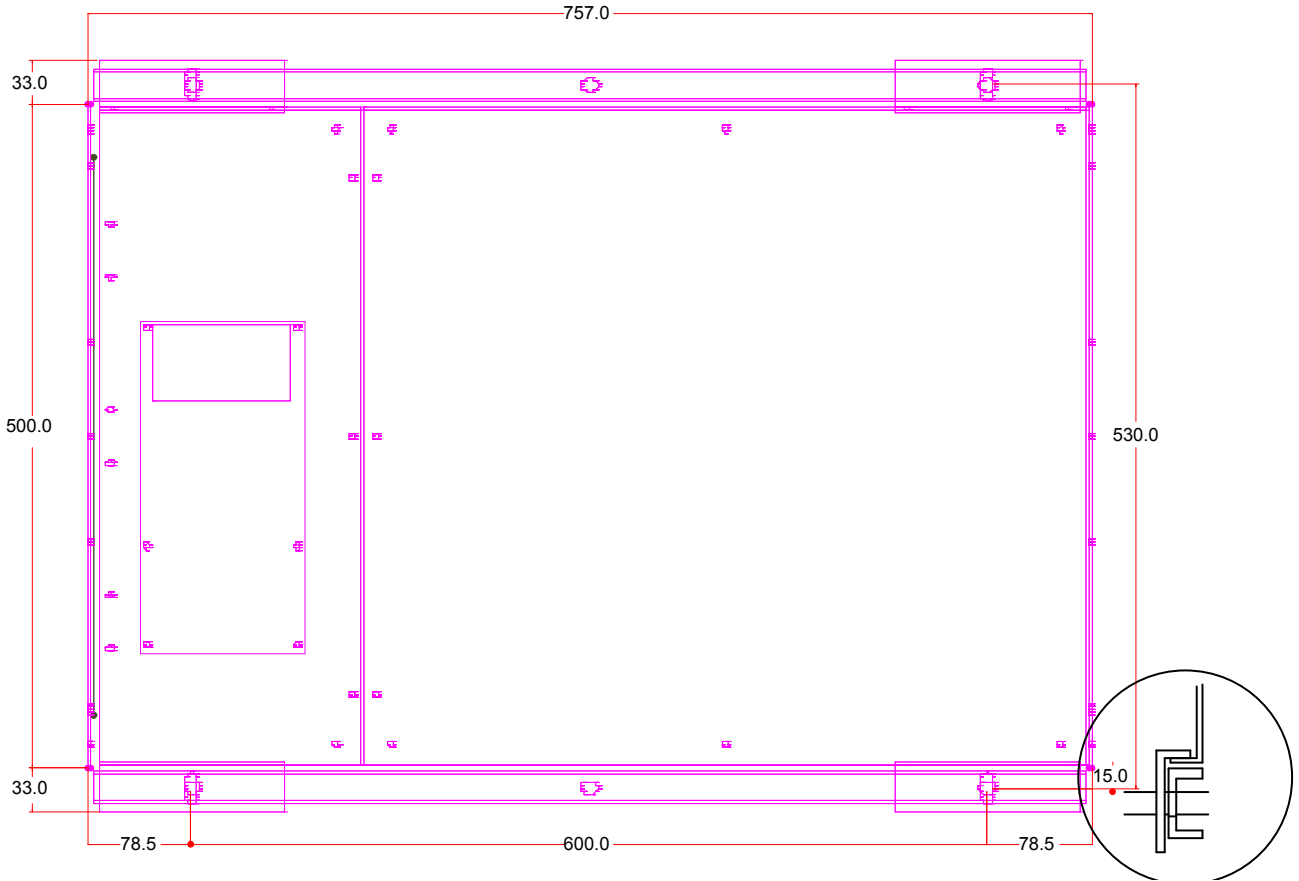
Control wiring is identical to that for the STC3000 range. The stack may be operated in phase angle or soft start burst fire modes.

Other Differences from the STC3000

- 1 Average load current is omitted from the user menu on the stack display, but appears on the communications menu, where it is the average of the two outer limb currents.
- 2 The firing angle range is 0-180 degrees.
- 3 Load voltage as seen on the secondary of the transformer (for a 1:1 transformer) is $(P1-P2) - (P2-P3)$, where P1 to P3 are the *phase* voltage phasors. The stack is designed to monitor a voltage phasor with this relationship, but scaled so that at full conduction the modulus of the voltage (displayed value) equals the line voltage rather than $\sqrt{3}$ x line voltage.
- 4 Current Limit operates only on the two outer (controlled) limbs.
- 5 Maximum load power is $\sqrt{3}$ x (line voltage) x (outer limb current).
- 6 For 160A and 200A units the maximum current which can be measured is 400A.

APPENDIX 2

Mounting Details for 1100A Air Cooled Unit



Depth
350mm with door closed
550mm with door open

Allow at least 150mm top and bottom for ventilation. The aluminium channel sections are mounted on 8mm studs fitted to the mounting plate. These may conveniently be screws screwed in to tapped holes from behind. The stack is then lifted onto the bottom channel. The L shaped clamps are then slipped on to the four outer studs so that they hook over the lips which run along top and bottom of the stack. Nuts are then tightened down on the clamps and the centre studs to secure the assembly.

Square holes are cut in the plate behind the fuses at the top of the stack. Bars may be fed through these from the front of the stack to which slings may be fitted for lifting.

ADDENDUM

Tables of Standard Calibration Values

The following tables show the standard calibration values set in the Calibration Menu. They represent the values of voltage and current which correspond with maximum count on the A/D converter - **not maximum ratings**.

Voltage Range	Maximum Voltage
250V (STC2500)	310.6 with h.f. isolator cards fitted
270V	313.2V with h.f. isolator cards fitted
480V	546.6 with 50Hz isolator transformers fitted 559.1 with h.f. isolator cards fitted
660V	

Current Rating	Maximum Current
80A	97
125A	160
160A	194
200A	266.7
315A	400
400A	480
600A	800
800A	1,000
1100A	1,500
STC2500	
80A	194
125A	320
160A	400
200A	400

Manual Issue Number and Applicable Software Versions

The issue number of this manual is R6, dated March 2006.

Issue R3 corrects errors in the semiconductor fuse type table for 600A and 800A units, and revises the fuse replacement instructions for these units.

Issue R4 added appendix for STC2500 series.

Issue R5 added details for 1100A air cooled unit

Issue R6 added details for 270V unit (revised 250V unit)

The manual is intended for use with stack software versions:-

S135E1R1 to R7 (with Modbus communications)	Does not support open delta / star load configuration
S136E1R1 to RF (with DeviceNet communications) configuration	Does not support open delta / star load configuration
S143E1R1 (with DeviceNet communications)	STC2500
S145E1R1 (with Modbus communications)	STC2500

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