

STAMFORD®

POWER FACTOR CONTROLLER

(PFC3) Part No: E000-21030.

(PFC3) Part No: E000-22090.

Installation and Adjustments Manual.



SAFETY PRECAUTIONS

Before operating the generating set, read the generating set operation manual and this generator manual and become familiar with it and the equipment.

SAFE AND EFFICIENT OPERATION CAN ONLY BE ACHIEVED IF THE EQUIPMENT IS CORRECTLY OPERATED AND MAINTAINED.

Many accidents occur because of failure to follow fundamental rules and precautions.

ELECTRICAL SHOCK CAN CAUSE SEVERE PERSONAL INJURY OR DEATH.

- Ensure installation meets all applicable safety and local electrical codes. Have all installations performed by a qualified electrician.
- Do not operate the generator with protective covers, access covers or terminal box covers removed.
- Disable engine starting circuits before carrying out maintenance.
- Disable closing circuits and/or place warning notices on any circuit breakers normally used for connection to the mains or other generators, to avoid accidental closure.

Observe all **IMPORTANT, CAUTION, WARNING, and DANGER** notices, defined as:

Important ! Important refers to hazard or unsafe method or practice which can result in product damage or related equipment damage.

Caution ! Caution refers to hazard or unsafe method or practice which can result in product damage or personal injury.



Warning !

Warning refers to a hazard or unsafe method or practice which CAN result in severe personal injury or possible death.



Danger !

Danger refers to immediate hazards which will result in severe personal injury or death.

Due to our policy of continuous improvement, details in this manual which were correct at time of printing, may now be due for amendment. Information included must therefore not be regarded as binding.

Front Cover Photograph

This photograph is representative only. Several variations are available within the range of generators covered by this manual.

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Cummins Generator Technologies STRONGLY recommends that when a PFC3 is used then "Loss of Excitation" tripping should also be used.

SECTION 1

GENERAL DESCRIPTION

The Power Factor Controller (PFC3) is designed to control the power factor reactive current (VAr) of a generator whilst running in parallel with the mains utility.

The PFC3 is also equipped with a voltage matching facility for use with automatic synchronisation equipment. This dispenses with the need for motorised potentiometers and allows a lower cost synchroniser to be used.

The PFC3 can also be connected to provide power factor correction of the incoming mains feeder by using the generator to supply the reactive current. A current limiting facility is provided to prevent generator overload.

The control loop within the PFC3 has two modes of operation to allow for the best response matching of the prime-mover governor and the generator voltage regulator. 'Dynamic Control' is the preferred method providing continuous correction and high accuracy. 'Deadband Control' provides an alternative means which allows the power factor (or VAr) to drift between presettable limits before any correction signal is given. This method is employed where system stability may be a problem.

The output of the PFC3 is internally limited to restrict the maximum (or minimum) voltage of the generator under abnormal operating conditions. This prevents the generator from trying to match an unrealistic mains voltage and also limits the consumer bus-bar voltage in the event of a mains failure.

The PFC3 incorporates an excitation limiting circuit to prevent the generator excitation from being driven to zero (or near zero) when operating at leading power factor.

Due to its flexibility the PFC3 can be used in many different single or multi-generator power schemes as shown in Fig 1a through Fig 1d and the more unusual applications may not be covered in this manual. If you are in any doubt as to the use of the PFC3 in your application please contact your nearest STAMFORD sales office for advice.

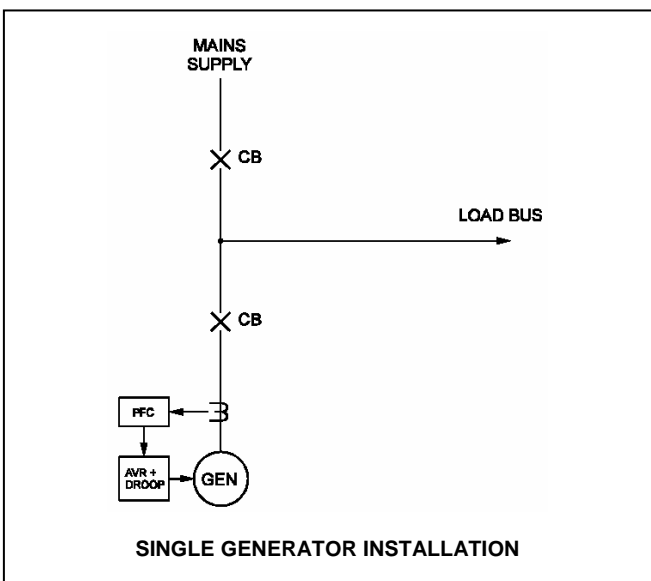


Fig. 1a Basic Power Factor Control

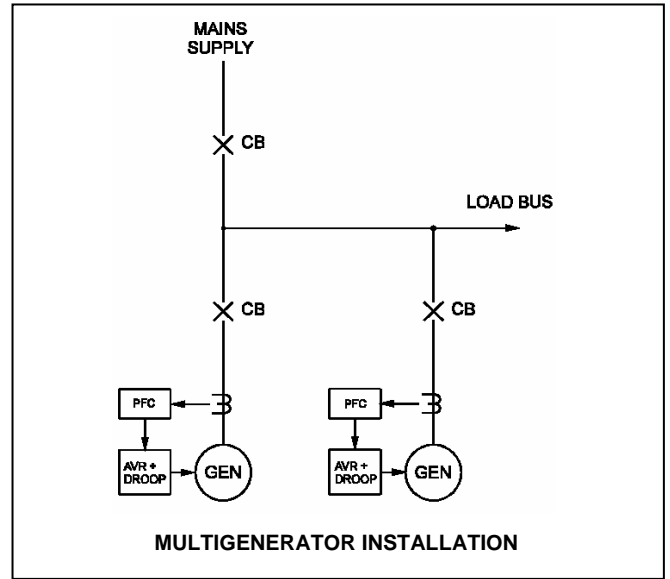


Fig. 1b Basic Power Factor Control

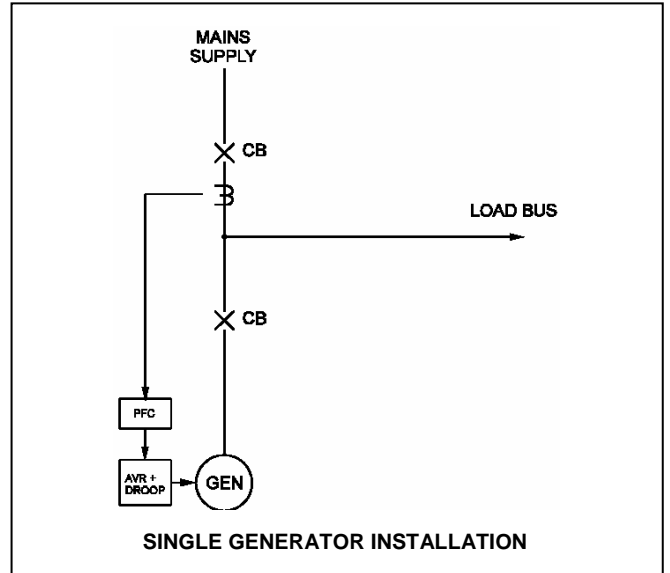


Fig. 1c Power Factor Correction

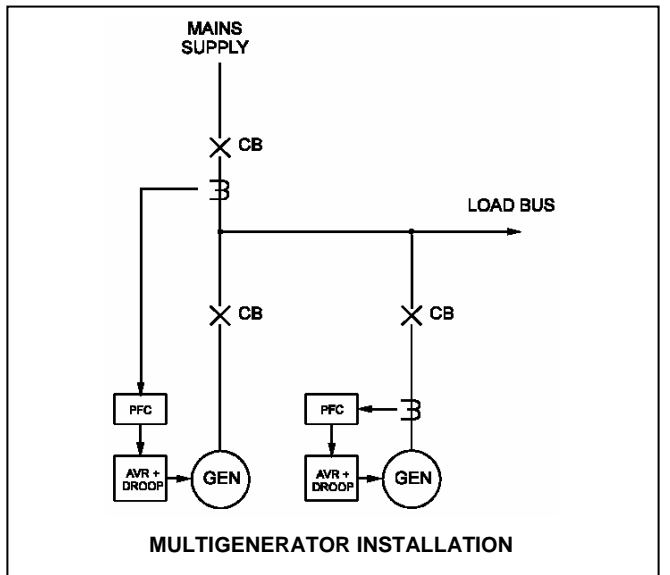


Fig. 1d Power Factor Correction

SECTION 2

PRINCIPLE OF OPERATION

The following description makes reference to the block diagram shown in Fig 2 (Principle of Operation).

generator current. The level at which current limiting applies is set using the appropriate circuit board control.

Signals representing generator voltage and current are fed into the PFC3 via isolation transformers and are used for various tasks within the unit.

Two measuring circuits (the Active Current Transducer and the Reactive Current Transducer) use both voltage and current signals to produce internal dc references proportional to generator kW and kVAr. The voltage input is also used to provide internal power supplies and further internal circuits measure the incoming voltage for voltage matching purposes.

The PFC3 is capable of operating in a variety of modes with internal switching circuits routing the necessary control signals to the main comparator/amplifier.

2.1 Power Factor Control Mode

In the 'Power Factor' mode of operation, the measured reactive current is compared to a proportion of the measured active current as set on the VAr/PF control potentiometer. If the measured reactive current rises above the 'kW' signal, then the PFC3 acts to reduce the internal set-point of the AVR (via terminals A1 and A2) and brings the generated VAr (and hence power factor) to the correct controlled level. If the measured reactive current is lower than required then the reverse action takes place. Under these conditions, closed-loop control of generator power factor is achieved.

2.2 VAr Control Mode

In the 'VAr' mode of operation, the measured reactive current is compared to a reference level derived from the setting on the PF/VAr control potentiometer. If the measured reactive current rises above this set-point, then the PFC3 acts to reduce the internal set-point of the AVR (via terminals A1 and A2) and brings the generated VAr to a controlled level. If the measured VAr is lower than the demand then the reverse action takes place. Under these conditions, closed-loop control of generated reactive current is achieved.

The PFC3 incorporates circuits to provide a level of protection to the generator not normally encountered in small/medium sized installations.

2.3 Generator Current Limiting

Under normal circumstances the sizing of the generator set will be such that the kW transfer to the mains (and hence the generated VAr) will be limited by the engine and its fuel system. In applications using the generator as power factor 'correction' of the incoming mains this limiting does not apply and the level of VAr demanded is a function of the feeder load. This can be many times the rating of the generator set (particularly under fault conditions) and must be protected against.

The PFC3 incorporates the necessary circuits to implement generator current limiting. The output of a separate reactive current measuring transducer is fed to the input of the main comparator/amplifier in such a way as to override normal PF or VAr control should excess current be detected. With this feature connected, normal power factor (or VAr) control is provided UNTIL the set current limit is reached, at which point the output to the AVR restricts further increases in exported (or imported)

2.4 Low Excitation Limiting

In applications requiring the generator to operate at leading power factor, the level of VAr imported may cause the generator to reach an unstable region due to self excitation. This can result in the loss of synchronisation and the associated large circulating currents may cause circuit breakers to trip or even equipment damage.

The PFC3 incorporates the necessary circuits to implement low excitation limiting. The output of a separate excitation voltage measuring transducer is fed to the input of the main comparator/amplifier in such a way as to override normal PF or VAr control should low excitation be detected. With this feature connected, normal power factor (or VAr) control is provided UNTIL the set low excitation limit is reached, at which point the output to the AVR restricts further increases in imported generator current. The level at which low excitation limiting applies is set using the appropriate circuit board control. The circuit is automatically disabled if left unconnected.

The PFC3 incorporates two more features which provide the user with the choice of additional operating modes not normally encountered in small/medium sized installations.

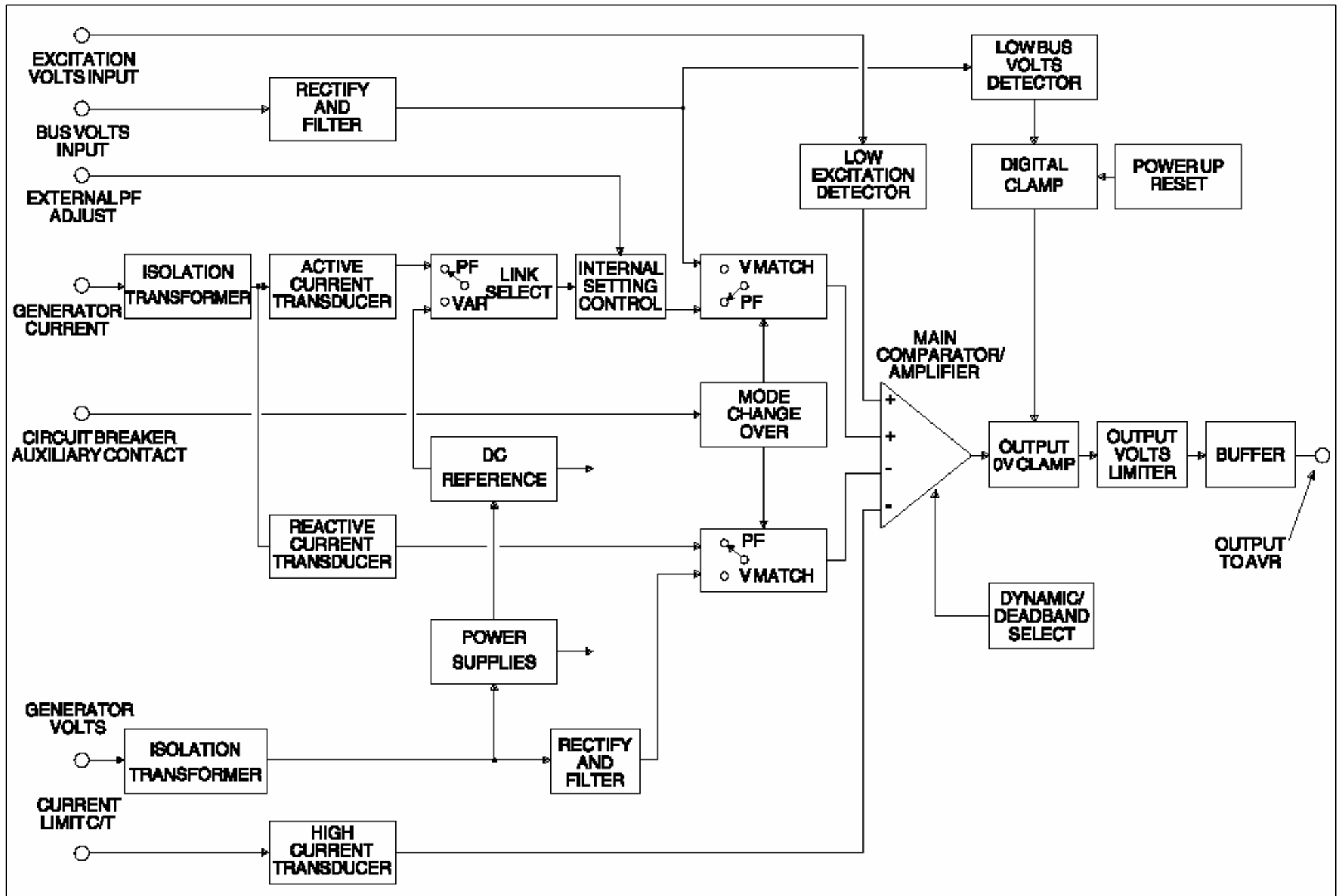


Fig. 2 Principle of Operation

2.5 Voltage Matching Mode

The PFC3 is equipped with a second set of voltage input terminals which are supplied (optionally) with a signal representative of the load bus voltage. It is essential that this signal is fully transformer isolated and is approximately 110Vac. If enabled; and prior to the arrival of the closure signal from the generator circuit breaker; the difference between the signals representing the generator and bus voltages is fed to the input of the main comparator/amplifier and adjusts the AVR set-point until both signals match. The circuit is automatically disabled when the generator circuit breaker closes. The table shown in Fig 3 explains the operation of the PFC3 when connected for voltage matching.

E1/E2 SUPPLY	CB1/CB2 CONTACT	L1/L2 SUPPLY	OPERATING MODE
ON	OPEN	NON PRESENT	AVR CONTROL ONLY
ON	OPEN	APPROX 110V	VOLTAGE MATCHING MODE
ON	CLOSED	X	PF CONTROL MODE
OFF	X	X	AVR CONTROL ONLY

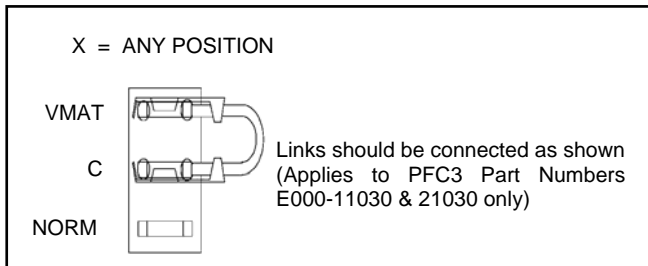


Fig.3 Voltage Matching Mode

2.6 Dead-Band or Dynamic Control Modes

The PFC3 can be set to operate in one of two control modes dependent upon the requirements of the installation. In dynamic mode, the output from the PFC3 continually adjusts the AVR set-point in response to the smallest change in power factor (or reactive current). In dead-band mode, the power factor (or reactive current) is allowed to vary between user settable limits before any adjustment is made. Dead-band mode results in a less accurate control but can eliminate problems of stability caused by interaction with engine governing systems.

Fig 4 (Dead-band vs Dynamic) shows diagrammatically the difference between dead-band and dynamic control modes and the effect of the [BAND] control as seen on a typical power factor meter.

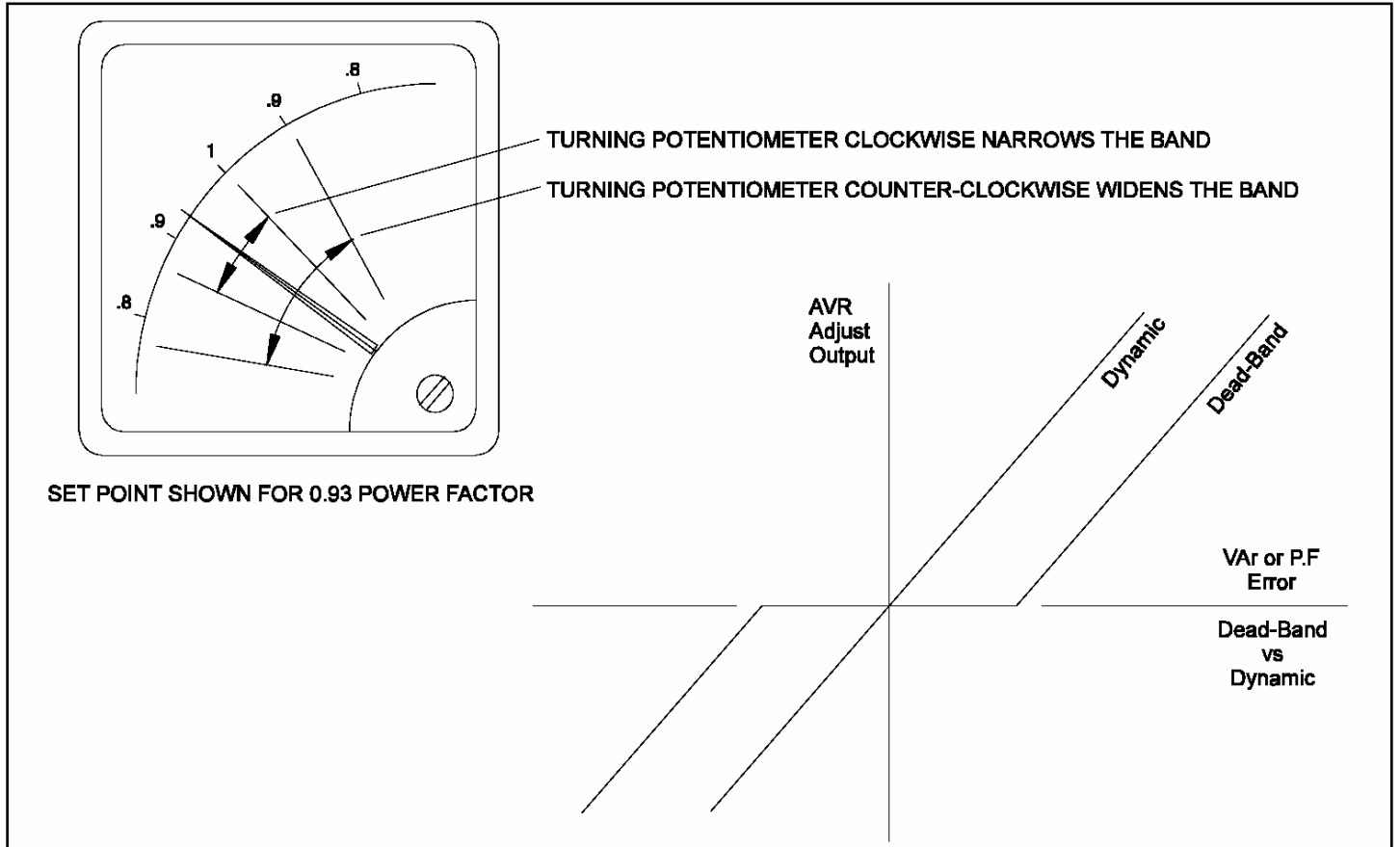


Fig. 4 Dead-Band vs Dynamic

Fig 5 (Dead-band Control Action) further explains the operation of the PFC3 when set in dead-band control mode.

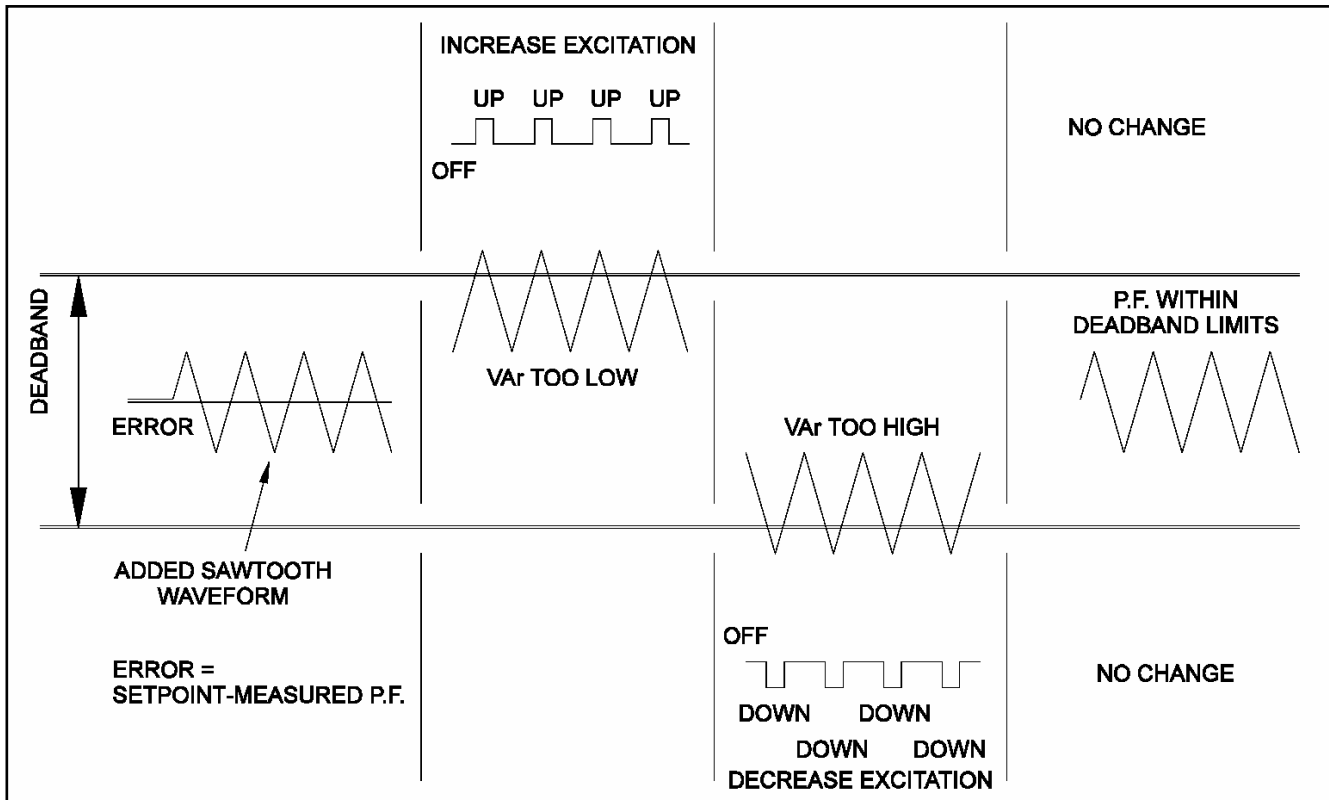


Fig. 5 Dead-Band Control Action

SECTION 3

INSTALLATION



DO NOT defeat or otherwise disable any system interlocks whilst installing this equipment.

Warning !



To prevent personal injury or damage to equipment, only qualified personnel should install or operate this unit.

Warning !

Important ! The use of Megger or High Potential test equipment may result in damage to this unit. Disconnect all leads before using such equipment.

3.1 General

The Power Factor Controller PFC3 incorporates as standard many features which enable it to be used in a wide range of applications. These features may be used in any combination depending upon the requirements of the end user.

It is assumed that the AVR is ready wired to the generator as specified in the appropriate machine wiring diagram.

In ALL applications of the PFC3, the AVR and generator MUST be equipped with a standard Quadrature Droop Paralleling kit. This is shown in all figures fitted in 'W' phase (the more normal position). For exact details refer to the wiring diagrams supplied with your generator.

The PFC3 should be located in a clean, vibration free environment, typically on the back panel of a control cubicle. If the unit is for machine mounting it will have been supplied without metalwork and MUST be fitted on anti-vibration mounts equal to those of the AVR.

All wiring should be carried out using cables rated at 6A/600V (minimum 0.75mm sq : 20AWG). For details of the AVR wiring, reference should be made to the wiring diagrams supplied with your generator.

Different applications may demand the installation of one or more of the optional features offered in the PFC3. Four typical configurations are described in this manual.

Fig 6 - Basic Operation - Power Factor Control of Individual Generators

Fig 7 - Replacing earlier VAr2 with the PFC3

Fig 8 - Maximum configuration - All Options Fitted

Fig 9 - PFC3 used for Power Factor Correction

IF IN DOUBT - REFER TO FACTORY

3.2 Generating Set Protection; General

Unless adequate protection is installed, engine control system malfunction or poor set-up can cause engine over-load or reverse power conditions resulting in damage to the engine.

Generator control system malfunction or poor set-up can cause generator over-current or loss of synchronism (pole-slipping) resulting in severe damage to the generator.

Generator Over-current Protection

It is the responsibility of the Generating Set Assembler to ensure that adequate protection systems are installed to trip the generator circuit breaker in the event of generator over-current.

Excitation Loss Protection

It is the responsibility of the Generating Set Assembler to ensure that adequate protection systems are installed to trip the generator circuit breaker in the event of loss of synchronism. We can supply a suitable unit for linking with the generator circuit breaker and control gear. Please refer to factory for details.

Automatic Synchronisers

It is the responsibility of the Generating Set Assembler to ensure that adequate protection systems are installed for Automatic Synchronising of AC Generators.

The following Automatic Synchroniser settings are recommended when using PFC3:-

Generator frequency mismatch 0.1 Hz
Voltage mismatch +/-3%
CB closing angle +/-10 degrees
Over/Under Voltage Protection

It is the responsibility of the Generating Set Assembler to ensure that adequate protection systems are installed to prevent damage to the generator or connected equipment in the event of over or under voltage caused by malfunction/poor set-up of the control system.

3.3 Basic Operation - Power Factor Control of Individual Generator(s) - Fig 6

This is the simplest configuration involving one or more generators coupled to the mains bus.

3.3.1 Voltage Input (E2 , E1)

These are connected to the generator output terminals (normally 'U' phase and Neutral) and act as the power supply to the unit as well as its sensing input. The maximum voltage allowed at these terminals is 277Vac/60Hz. If local regulations demand supply fuses, then these should be rated at 5A.

3.3.2 Current Input (S1 , S2)

These are connected to the generator current sensing C/T having a secondary rating of 5A. This MUST be positioned in the correct phase and with the correct polarity for successful operation of the PFC3. See wiring diagrams for details of your particular machine. If local regulations demand, then either lead S1 or S2 may be grounded.

3.3.3 AVR Control Output (A1 , A2)

These are connected directly to the corresponding terminals on the AVR. Should the cable length between the PFC3 and the AVR exceed 5m (16ft) then it is advisable to use screened leads with the cable screen connected to terminal A1.

Important ! Do NOT ground the screen at either end.

3.3.4 Circuit Breaker Input (CB1 , CB2)

Contact closure of these terminals switches the PFC3 into power factor (or VAR) control operation. These two terminals would normally be connected to a normally open auxiliary contact on the generator circuit breaker.

In the case of multi-generator installations, where the generator can run off-grid in parallel (island system), then a normally open auxiliary contact from the incoming mains circuit breaker/contactors MUST be connected in series with the 'E2' supply to the PFC. The voltage matching facility will then NOT operate in island operation. (See Fig 9).

Where the PFC3 is used to replace an earlier VAR-2 then the alternative wiring as shown in Fig 7 can be used. This will eliminate the need for any wiring changes when fitting the new PFC3. 'Voltage matching' will NOT operate with this wiring configuration.

3.4 Installing Options - Fig 8

If it is required to expand on the basic use of the PFC3 and to use one or more of the built-in options then the following notes apply.

Note: The numbers in the <brackets> refer to the relevant feature shown in Fig 8.

3.4.1 Remote Power Factor (VAR) Adjustment - <1>

Should front panel/remote adjustment of power factor or VAR be required then a 10k ohm / 1W potentiometer may be connected to terminals RX, RY and RZ as shown. The use of screened leads is **essential** with the screen connected to the adjacent '0V' terminal.

Important ! Do NOT ground the screen at the potentiometer end. Simply leave the screen unconnected and insulated.

When fitted, the external potentiometer has complete control over the PFC3 set-point and the on-board adjustment is no longer effective.

3.4.2 Remote Switching of Power Factor/Var Mode - <2>

Should front panel/remote selection of power factor or Var operating modes be required then a single pole changeover switch (rated at 1A/240V) may be connected to the terminals PF , C and VAR as shown. This will **replace** the link which is normally fitted. The use of screened leads is **essential** with the screen connected to the adjacent '0V' terminal.

Important ! Do NOT ground the screen at the switch end. Simply leave the screen unconnected and insulated.

3.4.3 Generator Current Limiting - <3>

Under certain operating conditions it is desirable to be able to limit the maximum current delivered by the generator. Connect the current transformer to the terminals 0V and ILIM as shown. The current transformer should have a secondary current output of 0.32A (class index 3.0) at 100% generator output and must be positioned in the correct phase and with the correct polarity for the successful operation of the PFC3. See loose leaf wiring diagrams for details of your particular machine. Bar mounted current transformers with the correct secondary rating and mechanical fixings are available from STAMFORD.

Important ! Do NOT ground either lead S1 or S2 of the current limiting C/T circuit.

3.4.4 Excitation Voltage Limiting - <4>

Under certain operating conditions it is desirable to be able to limit the minimum excitation voltage (and therefore excitation current) to prevent generator pole slipping. All that is required to enable this facility is to install two wires from X and XX (exciter field + and -) on the generator to the terminals X and XX on the PFC3. See loose leaf wiring diagrams for any additional details of your particular machine.

Important ! Do NOT ground either lead X or XX. 3.4.5 Voltage Matching - <5>

Under certain operating conditions it is desirable to use the voltage matching facility built into the PFC3. The inputs L1 and L2 have been designed to accept a standardised 110-120Vac supply from the customers low, medium or high voltage bus. In **ALL** cases the supply to the PFC3 **MUST** be isolated using a suitable transformer but unlike the other unit inputs, the phasing is unimportant. The input burden is typically 5VA.

Important ! Do NOT ground either lead L1 or L2.

3.5 PFC3 used for Power Factor Correction - Fig 9

It may be a requirement of certain applications to use the installed generating capacity in conjunction with the PFC3 to 'correct the power factor' of the incoming mains supply (at the consumers incoming tie with the mains). In all cases it is necessary to protect the generator against excessive current demand by fitting the current limiting option.

The current limiting transformer(0.32A sec) MUST be fitted in the generator output (as shown in Fig 9) and must be correctly phased.

The power factor control current transformer (5A sec) MUST be fitted in the incoming mains tie with the correct position and phasing. This is usually 'U' phase but local variations may be 'A' phase, L1 or cables 'red' in colour.

IF IN DOUBT - REFER TO FACTORY

NOTE (1) AVR CONNECTIONS OMITTED FOR CLARITY

NOTE (2) DROOP G/T POSITION: REFER TO GENERATOR WIRING DIAGRAMS FOR DETAILS

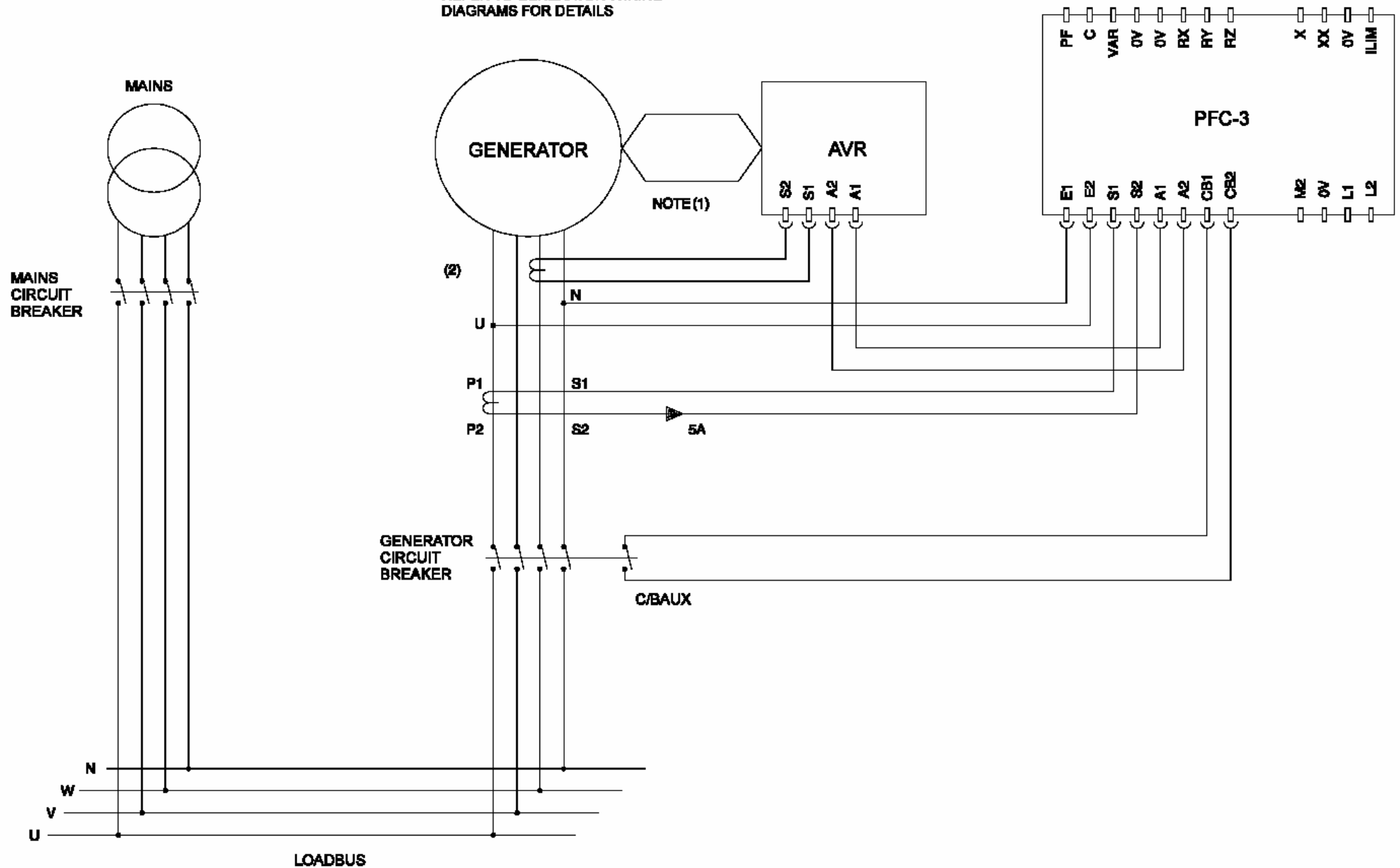


Fig. 6 Power Factor Control of Individual Generators

NOTE (1) AVR CONNECTIONS OMITTED FOR CLARITY

NOTE (2) DROOP C/T POSITION: REFER TO GENERATOR WIRING DIAGRAMS FOR DETAILS

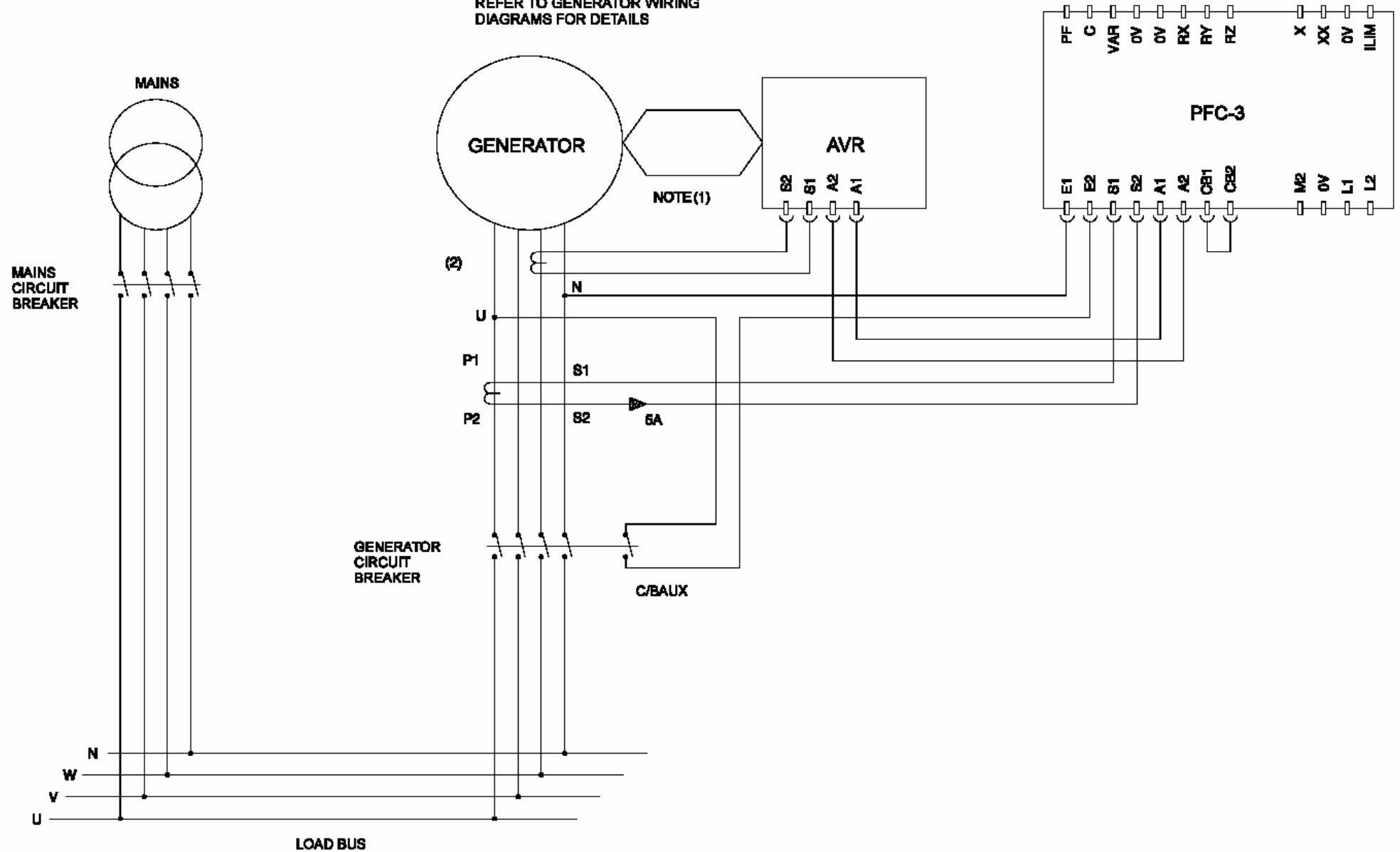


Fig. 7 Alternative Circuit Breaker Auxiliary Connection

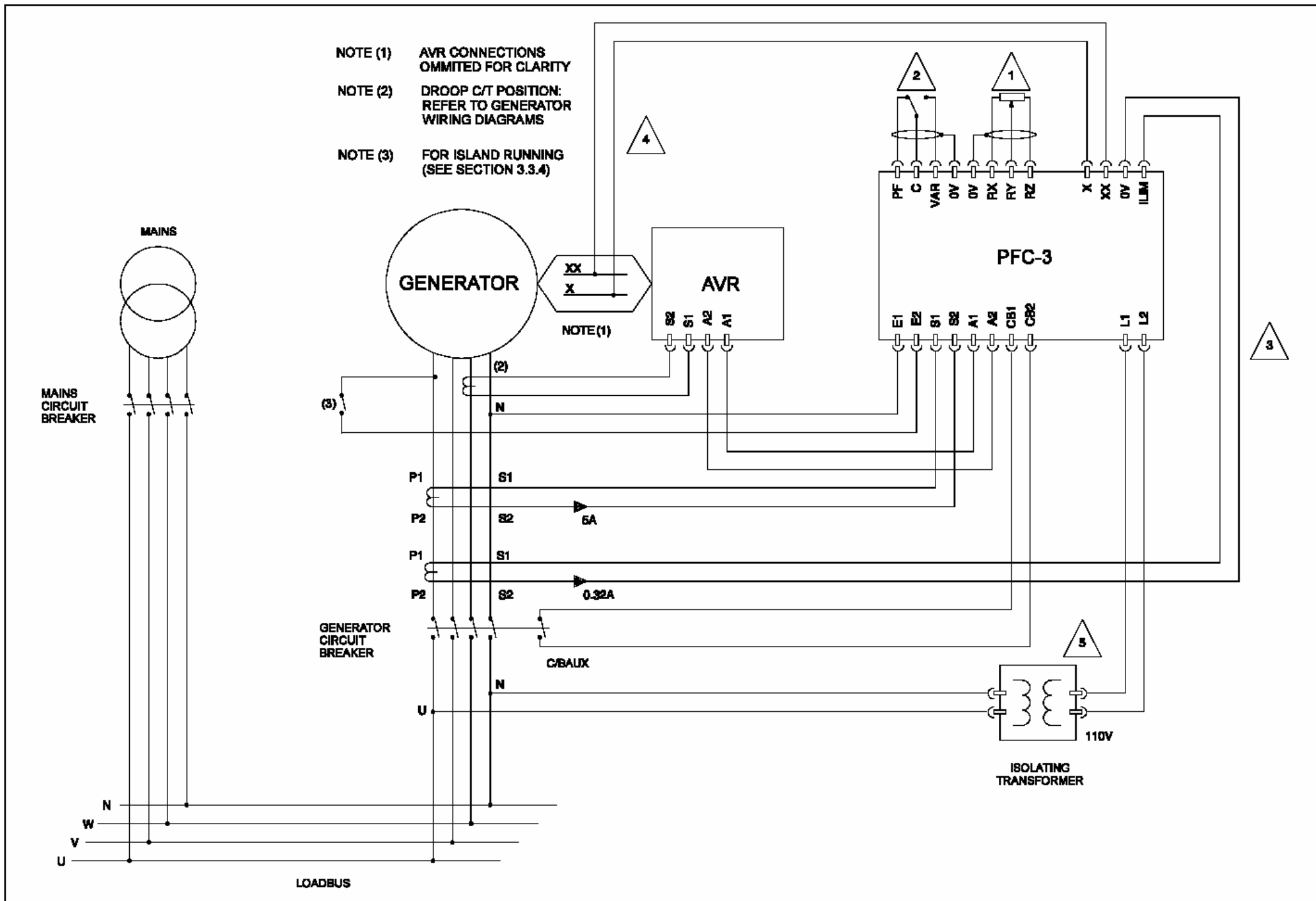


Fig. 8 Power Factor Control All Options Fitted

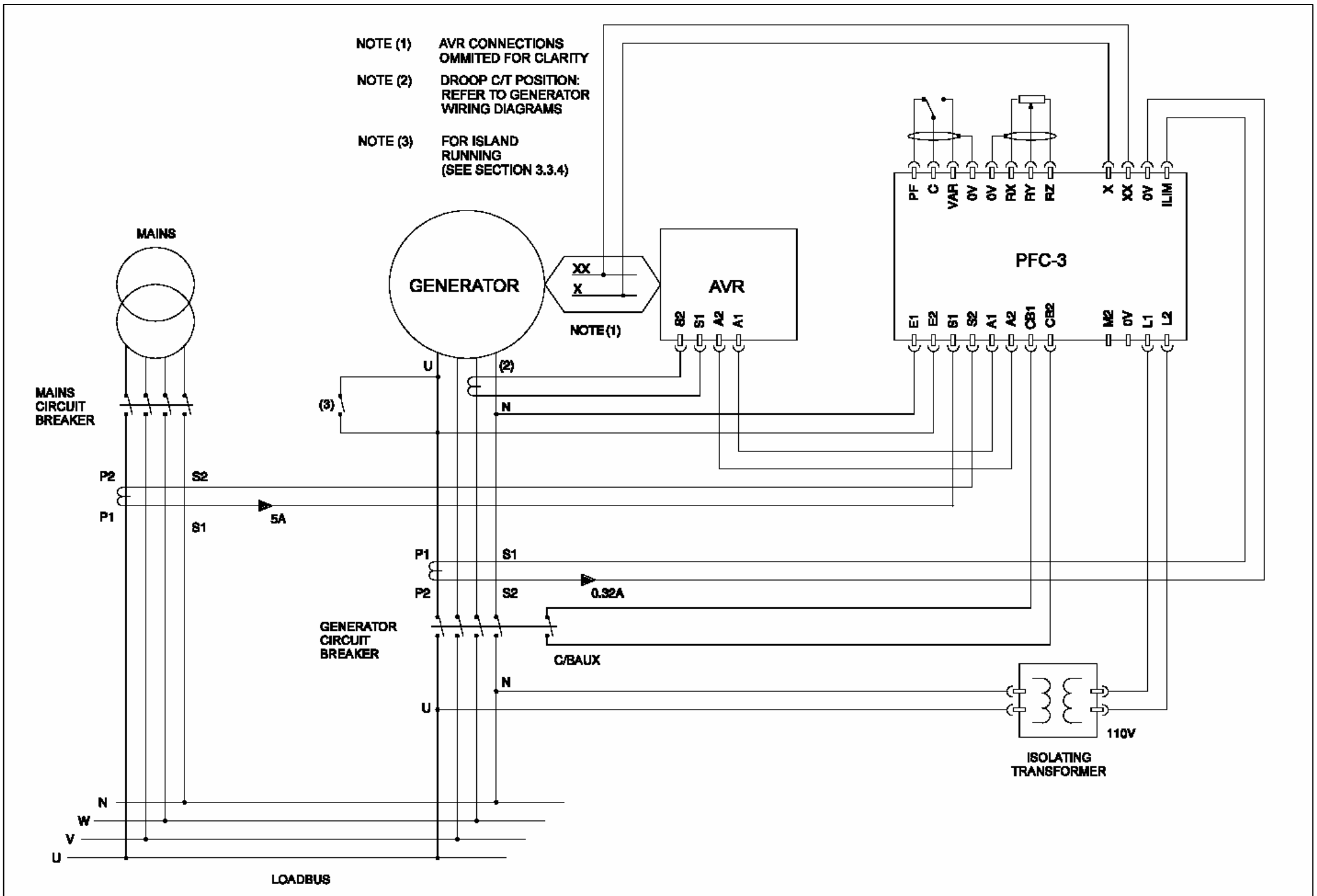


Fig. 9 Power Factor Correction of the Incoming Mains Supply

SECTION 4

COMMISSIONING AND ADJUSTMENTS

THERE ARE TWO VERSIONS OF PFC3
PFC3 E000-21030 has BLACK encapsulation
PFC3 E000-22090 is a GREEN board with clear encapsulation
Differences in features and commissioning are referred to where appropriate



Warning !

To prevent personal injury or damage to equipment, only qualified personnel should install or operate this unit. During commissioning the engineer will have access to live components and terminals. Maximum care should be taken when making adjustments not to contact live parts. Refer to the generator and switch-gear manufacturers handbooks for other safety notices.



Warning !

The following commissioning procedures cover ONLY the features of the PFC3. They DO NOT cover such matters as electrical installation, phase sequence, switchgear or engine controls.

Important ! The use of Megger or High Potential test equipment may result in damage to this unit. Disconnect all leads before using such equipment.

4.1 Installations

ALL Installations:

- Follow section titled:
4.2 Commissioning Basic System

Installations making use of one or more of the optional features:

- Follow sections titled:
4.2 Commissioning Basic System and:
4.3 Commissioning Options

Installations configured for power factor correction:

- Follow sections titled:
4.2 Commissioning Basic System and:
4.4 Power Factor Correction

4.2 Commissioning Basic System

The design of installations involving the paralleling of private generators with the mains supply will be regulated by the local generating authority. It is the responsibility of the commissioning engineer to ensure that the necessary approval has been granted before any paralleling operations are carried out.

The commissioning engineer should also be satisfied that all system protection equipment is correctly installed, adjusted and working and that ALL 'site' safety procedures have been observed.

Before running the generator, the installing/ commissioning engineer should ensure that all equipment is correctly installed and that the generator set is safe to start. They should also have studied the section on user adjustable controls and selection links and should have become familiar with their function. If the generator set controls are normally set to apply load automatically then this feature should be inhibited or switched to 'manual'.

Important ! All paralleling operations must be carried out in compliance with the generator set designers/ installer's instructions. We accept no responsibility for equipment damage caused by incorrect paralleling operations.

Important ! During commissioning of the PFC3 any connections to terminals RX, RY and RZ must be removed.

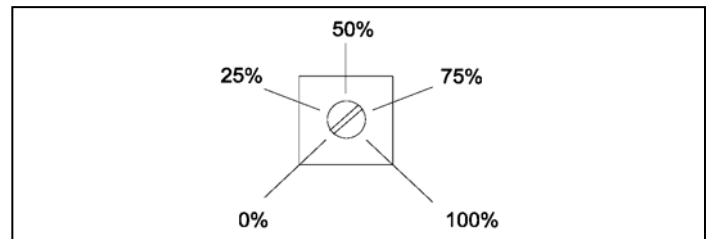
Commissioning of the basic system is best carried out in three parts:

1. Preliminary Adjustments.
2. Checking the Droop C/T polarity and setting.
3. Checking of the PFC3 C/T polarity and setting.

4.2.1 Preliminary Adjustments

Before starting the generator set the commissioning engineer should first make sure that the user adjustable controls and selection links on the PFC3 and certain AVR controls are set as follows.

Note: CW = Clockwise Adjustment
CCW = Counter-Clockwise Adjustment

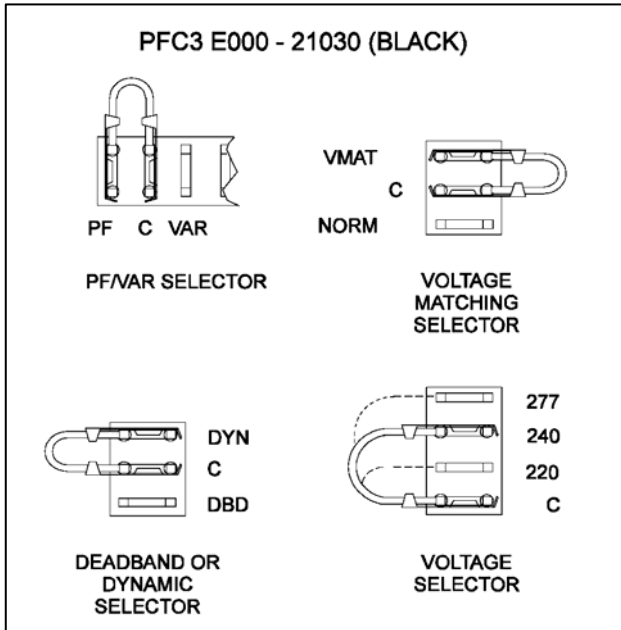


Scaling as shown below

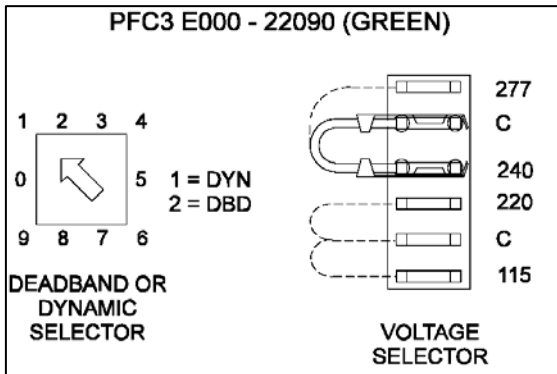
AVR controls Droop - Fully CW (100%)
Trim - Fully CCW (0%)

PFC3 controls PF/VAR - Midway (50%)
 ILIM - Fully CCW (0%)
 GAIN - Fully CCW
 BAND - Fully CCW
 XLIM - Fully CCW

Isolate voltage matching transformer if fitted.



The Input Voltage Selection should be made appropriate for the application (normally line-neutral voltage). Refer to wiring diagrams supplied with your machine for further details.



4.2.2 Droop Setting

- Having checked that the generator is safe to run, the set should be started and run up to nominal speed and the AVR volts control adjusted to give an output voltage equal to that of the installation mains.
- Paralleling of the generator should now be carried out in accordance with the set/installation designers instructions. At this stage the commissioning engineer should take particular notice of the generator output current.
- If the generator current rises to an abnormally high level then the generator circuit-breaker should be opened immediately and the set stopped. In this event it is more than likely that the droop C/T or its wiring is reversed. If this is the case then the droop C/T connections to the AVR should be reversed and the start-up and initial paralleling procedure repeated. Do not confuse the AVR droop connections S1/S2 with the PFC3 current transformer connections S1/S2.
- After successful paralleling has been achieved, load should be applied and increased to approximately 50%. At this point the power factor should still be near unity. The voltage across terminals S1 and S2 on the AVR should now be measured (0.5 to 2.5Vac) and recorded for future reference. The generator output current should be stable with only minor variations reflecting small changes in the system (mains) voltage.
- The droop circuit polarity has now been verified and must now be set to a level for the best operation of the PFC3.
- Open the generator circuit breaker and stop the set before proceeding.

The optimum position of the droop control can now be found by using the following formula:

$$\text{Potentiometer Position (\%)} = \frac{d}{\text{AVR S1 S2 voltage}} \times 100\%$$

Potentiometer Position 0% = Fully Anti-Clockwise
 100% = Fully Clockwise

d = 0.25 for SX440 and MX341 AVRs
 d = 1.00 for MX321 and SX421 AVRs

e.g If the measured voltage across S1 and S2 on the SX440 AVR at half-load was 0.5V, then:

$$\text{Potentiometer Position (\%)} = \frac{0.25}{0.5} \times 100\% = 50\%$$

The AVR Droop potentiometer should therefore be set to the midway position.

If the result of this calculation is greater than 100% then it suggests that the droop C/T ratio is incorrectly rated (or fitted) and the correct device should be obtained before proceeding further.

The Droop equipment is now set.

4.2.3 PFC3 Setting

Having set the AVR droop equipment the PFC3 can now be commissioned as follows.

Important ! Make sure that the AVR Trim control is in the fully counter-clockwise (0%) position.

- Start the generator, synchronise it with the mains supply and apply load as described in the section on droop setting. At this point the power factor should still be near unity.
- The 'CB' LED on the PFC3 will indicate that the generator circuit breaker is closed. Check that this is illuminated.
- Measure the voltage across terminals S1 and S2 on the PFC3 (at half-load). This voltage should be between 50- 180mVac. If this is not the case then it suggests that the PFC3 C/T is incorrectly rated (or fitted) and should be replaced by the correct unit before proceeding further.

Note: At this point the generator is under the control of the AVR and droop transformer and the following steps simply check the basic functions of the PFC3 before it is put into full operation.

- Slowly adjust the PF/VAR control on the PFC3 to its fully anti-clockwise position (maximum lag). If the generator current rises to a high level as the adjustment is made, return it to its central position immediately and re-check that the AVR Trim control is in the fully anti-clockwise position.
- After a delay of approximately 20 seconds measure the voltage appearing across AVR terminals A2 and A1. This should be between +2Vdc and +5Vdc (meter leads: positive on A2, negative on A1). If the reading is of opposite polarity (-2Vdc to -5Vdc) then stop the generator and check the wiring between the PFC3 and the AVR (A1 and A2). If the wiring is correct then simply reverse the connections S1 and S2 to the PFC3.

Note: Certain 'third-party' current transformers do not comply with standard marking conventions.

- Re-start and parallel the generators, apply load and confirm that the voltage across AVR terminals A2 and A1 is now of the correct polarity.
- Slowly adjust the PF/VAR control on the PFC3 to its fully clockwise position (maximum lead) and measure the voltage appearing across AVR terminals A2 and A1. This should be between -2Vdc and -5Vdc (meter leads: positive on A2, negative on A1).

Stop the generator and turn the PF/VAR control on the PFC3 to the midway position. Turn the Trim control on the AVR to the fully clockwise position.

The PFC3 is now ready for operation.

4.3 Commissioning Options

Before the generator and its PFC3 is put into full operation it will also be necessary to set-up any of the optional features being installed. The operation of the PFC3 and AVR will have already been checked during the Commissioning of the basic system.

4.3.1 Voltage Matching Option

The Voltage Matching Transformer /Isolating Transformer (user supplied) should be connected as shown in Fig 9. With the system voltage and frequency at its nominal value, the secondary voltage (applied to PFC3 terminals L1 and L2) should be nominally 100Vac to 120Vac. The phasing of this signal is unimportant.

- Check that the voltage matching selection link is set to **VMAT E000 - 21030 (BLACK)** only.
- Turn the AVR Trim control fully anti-clockwise. Start the generator and run-up to rated voltage and frequency. **DO NOT PARALLEL.** Set the AVR volts control to give a generator terminal voltage that is in the centre of the expected Mains Utility Supply Voltage variation, e.g. If the expected Supply Voltage variation is 380 - 440V then set the generator terminal voltage to 410 volts.
- If the expected Supply Voltage variation exceeds the rated generator voltage stated on the nameplate, then stop the generator and consult the factory before proceeding further.
- Stop the generator and turn the AVR Trim control to the midway position.
- Start the generator and run-up to rated voltage and frequency. **DO NOT PARALLEL.**
- The VMAT LED should be illuminated E000 - 22090 (GREEN) only.
- The PFC3 will now gradually adjust the generator voltage to a new value which could be higher or lower than the bus voltage. Return the generator voltage to the 'matched' condition by slowly adjusting the **BUSV** control on the PFC3. If the generator volts are 'High' (compared to the bus) then the **BUSV** control should be adjusted slowly anticlockwise to equalize the bus and the generator voltages. If the generator volts are low then **BUSV** control should be adjusted clockwise.

Note: The circuit may take several seconds to return the generator voltage to the 'matched' condition. Due allowance must be made for this delay whilst making adjustments. For best results it is advisable to adjust in small steps and wait for the response.

Stop the generator and turn the AVR Trim control to the fully clockwise position.

The voltage matching option is now set.

4.3.2 Current Limiting Option

Current limiting should only be used when the PFC3 is connected for Power Factor correction of the incoming main feeder.

If the generator has the MX321 AVR and separate current limiting equipment fitted, this should be disabled by turning the **ILIM** control on the **AVR** fully **CLOCKWISE**.

The Current Limiting Transformer should be connected as shown in Fig 8 (feature 3). The phasing of this C/T is important.

For power factor correction applications it is usual to have two current transformers (C/T's) fitted in the generator terminal box, one with a 5 Amp secondary and one with a 330 mA secondary. There will also be a 5 Amp secondary CT fitted to the Mains Utility incoming feeder.

The 5 Amp Generator mounted CT is used for normal Commissioning and Generator Power Factor Control. This will be unused in Power Factor Correction operation and provision should be made for connection of a shorting link to prevent an open CT secondary.

The 330mA Generator mounted CT is used for measuring generator reactive current for the I Limit feature.

The 5 Amp CT connected to the Mains Utility incoming feeder is the one used in service for Power Factor correction. This CT could be carrying site current and provision should be made for the connection of a shorting link to prevent an open CT secondary.

1. With the generator stationary connect the generator mounted 5 Amp CT to the PFC3 S1 S2 terminals, observing polarity. Generator wiring diagrams will show the full details.
2. Connect the Generator mounted 330mA I Limit CT to the PFC3 connections 0V / ILIM, S1 to ILIM, S2 to 0V. Generator wiring diagrams will show the full details.
3. Turn the PFC ILIM potentiometer fully anti-clockwise.
4. Set PF / VAR selector to PF.
5. Parallel generator to mains network and run at maximum kW set-point rating.
6. Adjust the PFC3 to give a generator PF of 0.9 lagging.
7. Calculate the operating Per Unit Reactive Current (PURC) against generator rating :-

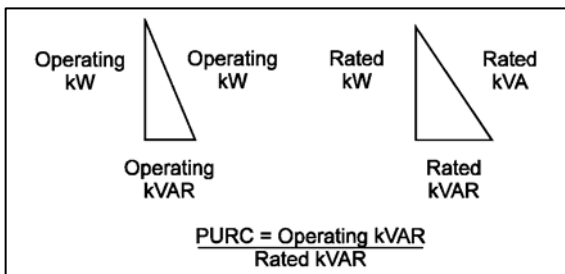


Fig. 10

8. Measure TP2 voltage between 0V and TP2, meter neg (-) on 0V. This should be between +2 and +4V dc. For the location of TP2, see the label drawing on the PFC3 access cover plate or PFC3 manual.
9. Calculate required setting of TP2 voltage :-

$$[(1 - \text{PURC}) \times (\text{TP2 voltage} + 0.3)] - 0.3$$

10. Turn ILIM slowly clockwise. TP2 voltage should reduce in value. If it rises then stop generator and reverse the S1 S2 connections to the PFC3 0V and ILIM terminals. Retest from line 5.
11. Adjust ILIM until TP2 = Required voltage as calculated in line 9.
12. Stop the generator and remove the generator CT connections S1 S2 on the PFC3 and terminate the generator CT wires with a suitable shorting link.
13. Connect the mains feeder CT S1 / S2 cables to the PFC3 (observing polarity) and remove the mains feeder CT shorting link.
14. Turn the PFC3 PF / VAR setting potentiometer to the centre position.
15. Start the generator and parallel to the mains network.
16. Set the generator to the required operating kW.
17. Adjust the desired mains power factor using the PF /VAR setting potentiometer on the PFC3.
18. Set-up is now complete.

4.3.3 Low Excitation Limiting Option

Low Excitation Limiting should only be used when the generator is to be operated at leading power factor.

The Excitation Limiting input (X and XX) should be connected in parallel with the generator exciter field winding as shown, in Fig 8 (feature 4). The two exciter field connections (X and XX) will normally be found at the auxiliary terminal block within the generator. If these terminals do not exist, a suitable connection block can be obtained from STAMFORD.

Connect a digital multimeter as follows:

Negative Input to 0V (any of four) on the PFC3
 Positive Input to Test Point TP4 on the PFC3
 Set to measure on the 20Vdc scale

- Set the voltage matching selection link to **NORM**.
- Start the generator and run-up to rated voltage and frequency. **DO NOT PARALLEL**.
- Using the graph shown in Fig 11, adjust the low excitation limit control **XLIM** to set the voltage on the test point as indicated.
- Stop the generator and set the voltage matching selection link to its original position.

The low excitation limiting option is now set.

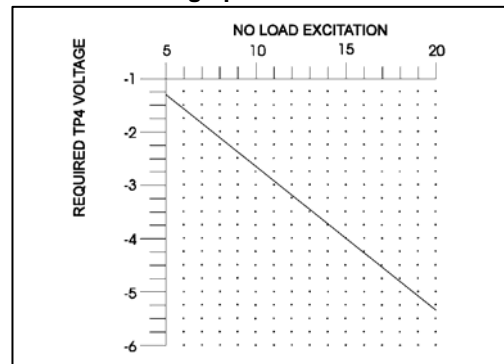


Fig. 11 Low Excitation Limit Setting

4.3.4 Dead-Band and Dynamic Control Options

For the majority of applications, dynamic control is recommended as this is the more accurate and has the fastest response time of the two operating modes. However, if instability is encountered, then dead-band control may provide the necessary flexibility within the generator control loop to overcome this undesirable effect.

In dynamic mode, correction signals are continually fed to the AVR in order to maintain the set power factor. In dead-band control, the power factor is allowed to 'drift' within pre-set limits before any corrective action is taken. Allowing the loop to 'open' in this way provides for a less accurate control but much improved stability.

In dead-band control mode the correction signals take the form of pulses which change in width as the error (deviation from setpoint) changes.

The three controls which alter the overall performance of the PFC3 in dead-band mode are as follows:

- [BAND] Adjusts the Dead-band width in dead-band mode and allows the PF (or VAr) to drift between wider limits before AVR set-point adjustments are made.
- [CLK] Sets the rate at which AVR adjustments are made (in dead-band mode only).
- [GAIN] Makes the controller more or less sensitive to deviation from the set-point (in dead-band mode only) by altering the size of each adjustment.

For more information on the above adjustments see the section on User Adjustable Controls and Selection Links.

If dead-band mode is selected it is strongly recommended that the Gain and Band are set fully counter-clockwise (lowest gain, widest band). These controls can then be adjusted from their initial positions by trial and error to find the optimum setting.

As an aid to setting, red light emitting diodes (LEDS) indicate increase (INC) and decrease (DEC) excitation signals. The clock (CLK) indicates the rate of error correction signals and is pre-set at the factory at approximately one per second.

4.4 Power Factor Correction

With the generator operated as a power factor correction system it will be possible to overload the generator windings with a PFC3 setting of near unity power factor WITHOUT overloading the engine/prime-mover. In this situation the generator has to supply the necessary reactive current to the load in order to correct the mains supply power factor to that set on the PFC3. The generator output current is therefore independent of the governor setting (kW) and/or the power factor setting on the PFC3.

Before the generator is put into operation in this mode the Current Limiting option MUST be installed and commissioned (see section 4.3.2).

The commissioning engineer should also attempt to establish the nature of the site load. Since the generator will be expected to supply all or part of the reactive component of load current, any condition which would result in the generator operating at leading power factor must be treated with care. Operating the generator at leading power factor will cause the excitation to be reduced to a level where loss of synchronisation may occur. This may cause protective equipment to operate and the loss of the correcting influence of the generator or, in extreme cases, equipment damage.

Where these conditions are likely to exist it is recommended that the Low Excitation Limiting option be used (see section 4.3.3). Use of Excitation Loss equipment is also strongly recommended for all installations where industrial ac generators run in parallel with the mains supply (see section 3.2).

SECTION 5

USER ADJUSTABLE CONTROLS AND SELECTION LINKS

Refer to Figs 12 and 13 for the location of adjustments and selection links.

Important ! Any control marked with an 'R' followed by a number is NOT a user adjustable control. Do NOT adjust unless instructed to do so by the manufacturer.

Important ! Make sure you fully understand the function of each control and link before making any adjustments.

Note: W = Clockwise Adjustment
CCW = Counter-Clockwise Adjustment

[PF/VAR] Is the main Power Factor or Reactive Current setting control dependent upon which mode of operation the PFC3 is selected for.

PF mode CCW = Lag
Midway = Unity Power Factor
CW = Lead

VAr mode CCW = Export (generate) VAr
Midway = Minimum VAr
CW = Import (absorb) VAr

[STAB] Adjusts the effective 'damping' within the PFC3

CW = Fully damped (most stable)
CCW = Minimum damping

[BAND] Adjusts the Dead-band width in dead-band mode and allows the PF (or VAr) to drift between wider limits before AVR set-point adjustments are made.

CW = Narrow Band
CCW = Wide Band

[CLK] Sets the rate at which AVR adjustments are made (in dead-band mode only).

CW = Faster Rate
CCW = Slower Rate

[GAIN] Makes the controller more or less sensitive to deviation from the set-point (in dead-band mode only) by altering the size of each adjustment.

CW = Large Adjustments made
CCW = Small Adjustments made

[ILIM] When this option is wired/enabled, adjusts the level at which generator current limiting takes place.

CW = Decreases the current level
CCW = Increases the current level

[BUSV] When this option is wired/enabled, adjusts the relative proportion of bus volts applied to the main comparator/amplifier to make allowances for different user supplied isolation transformers.

CW = Increases generator voltage
CCW = Decreases generator voltage

[XLIM] When this option is wired/enabled, adjusts the lowest level of excitation permissible when operating at leading power factor.

CW = Raises the low excitation limit
CCW = Lowers the low excitation limit

The remaining controls are set and sealed at the factory:

TP1 - TP6 are used for special setting up procedures.

5.1 Light Emitting Diode (led) Indicators

(CB) Indicates closure of terminals CB1 and CB2 and that the PFC3 is operating in power factor (or VAr) mode.

(VMAT) To indicate presence of voltage matching signal. E000 - 22090 (GREEN)

(CLK) To indicate the rate of correction signals when operating in dead-band mode.

(INC) To indicate when the PFC3 is increasing the AVR set-point in dead-band mode.

(DEC) To indicate when the PFC3 is decreasing the AVR set-point in dead-band mode.

5.2 Selection Links & Switches

{ PF - C - VAR } Power Factor or VAr modes

{ NORM - C - VMAT } Normal or Voltage Matching modes
E000 - 21030 (BLACK)

{ 1 = DYN 2 = DBD } Dead-Band or Dynamic modes
E000 - 22090 (GREEN)

{ DBD - C - DYN } Dead-Band or Dynamic modes
E000 - 21030 (BLACK)

{ C - 220 - 240 - 277 } Input Voltage Selection
E000 - 21030 (BLACK)

{ 115 - C - 220 - 240 - C - 277 } Input Voltage Selection
E000 - 22090 (GREEN)

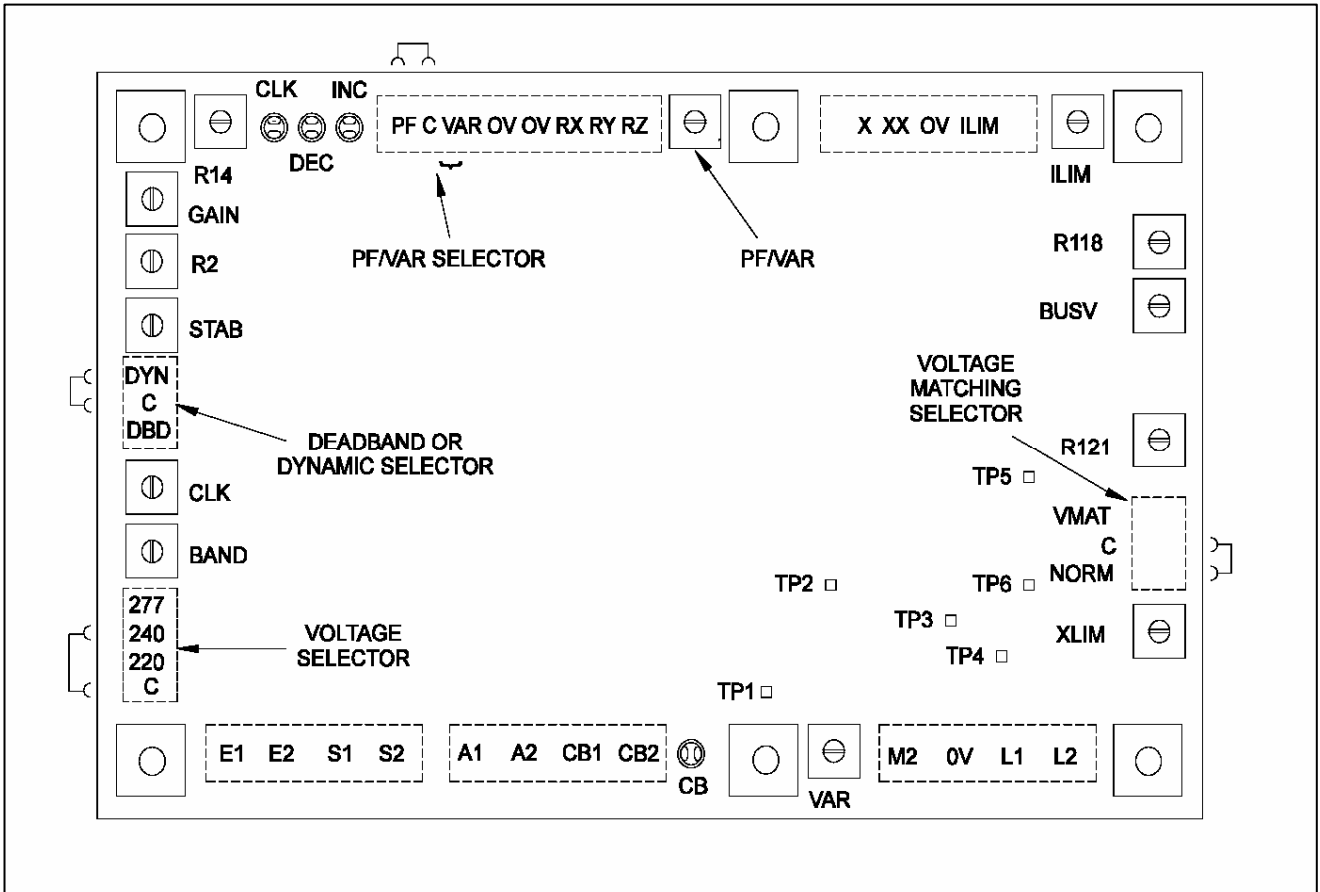


Fig. 12 PFC3 User Adjustable Controls and Selection Links Part number E000 - 21030 (BLACK)

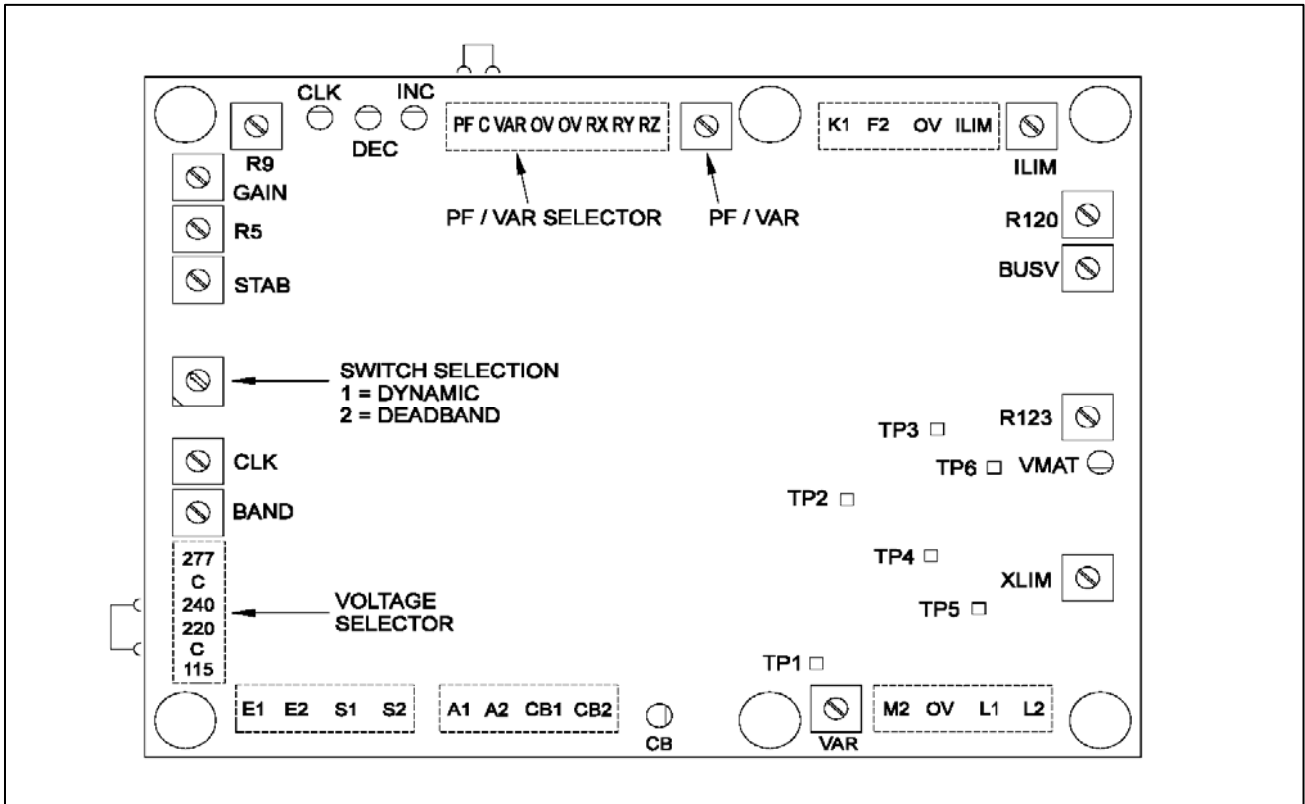


Fig. 13 PFC3 User Adjustable Controls and Selection Links Part number E000 - 22090 (GREEN)

SECTION 6

OPERATION

6.1 General

Important ! Before putting the generator into full operation the Trim control on the AVR MUST be set to the fully clockwise position.

Under normal circumstances the operation of the PFC3 is fully automatic and once commissioned the unit should continue to operate without further attention.

Once commissioning is complete it will only be necessary to set the operational power factor on the **PF/VAR** control on the PFC3. The actual operating point of the power factor controller will be determined by the application and the following notes are for guidance only.

6.2 Combined Heat And Power Installations

Installations where the generator is operated at a kW rating dependent upon the 'heat' demand from the site.

Normal PFC3 setting would be 1.0pf to 0.8pf lag to optimise the utilisation of the generator rating but care must be taken not to export unacceptable levels of VAR to the mains supply.

6.3 Peak Lopping Installations

Installations where the generator is used to supply all the site load in excess of a maximum set by the mains provider.

Normally the PFC3 would be set to generate at a power factor equal to the site load average and at a fixed power level (maximum rating of the set) in order to reduce the incoming demand on the mains to a minimum.

6.4 Power Factor Correction

The generator is used to provide the site VAR necessary to maintain the power factor of the incoming mains supply within fixed limits.

Normal PFC3 setting would be 1.0pf to 0.8pf lag to optimise the power factor of the incoming supply, care must be taken that the generator rating is not exceeded. The current limiting feature of the PFC3 MUST be used in this situation.

6.5 Synchronous Motors

Using an a.c generator as a synchronous motor will demand a setting of 1.0pf to 0.9pf on the PFC3.

Important ! Users of ac generators as synchronous motors must provide the necessary equipment and/or procedure for starting e.g pony motor.

When using an ac generator (equipped with a PFC3) as a synchronous motor, the wiring required is identical to that of generator applications. There is NO requirement to reverse C/T or any other phase sensitive connections.

6.6 Overvoltage

If at any time during generator operation, the terminal voltage exceeds the rated generator voltage stated on the nameplate, then stop the generator and consult the factory.

SECTION 7

TROUBLE SHOOTING

Under normal circumstances the operation of the PFC3 is fully automatic and once commissioned the unit should continue to operate without further attention. Should the system fail in service, the troubleshooting chart shown in Fig 14 will be helpful in identifying the cause.

Mains Utility Supply Voltage Variations

In some areas, large voltage variations can take place causing malfunction of the generator control system.

As stated in section 3.2, it is the responsibility of the Generating set Assembler to install adequate protection to safeguard the generator.

If satisfactory operation cannot be achieved then it would be advisable to carry out a Mains Utility Supply Voltage survey over a minimum period of 24 hours, recording the absolute maximum and minimum RMS voltages and also the largest step change. Consult the factory for advice.

The user is reminded of the following information relating to the paralleling of generators.

- The active power output (kW) of the set is controlled entirely by the engine governor and NOT by the generator AVR. Problems concerning kW fluctuations etc. are almost certainly to do with the engine fuel system and/or frequency control.

The reactive power output (kVAR) of the set is controlled entirely by the excitation system of the generator (i.e the AVR). Problems concerning reactive current (circulation/ fluctuation etc.) are almost certainly to do with the generator AVR and its associated equipment.

Spares & Service

A full technical advice and on-site service facility is available from our Service Department at Stamford or through our subsidiary Companies.

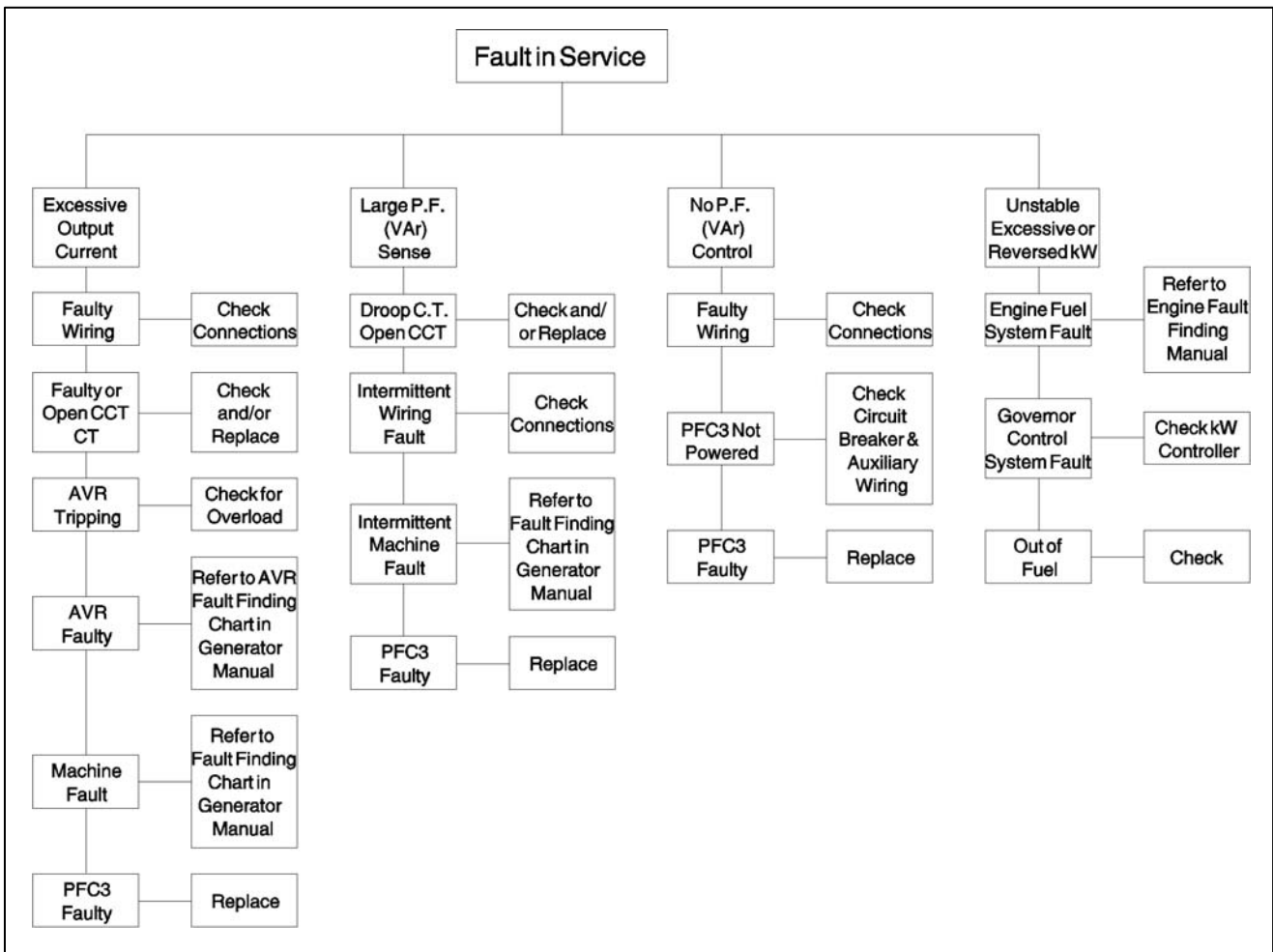
When ordering parts the machine Serial Number or Machine Identity Number and type should be quoted, together with the part description. The Serial Number is printed on the nameplate and the Machine Identity Number on two labels inside the terminal box.

Orders and enquiries for parts should be addressed to:

STAMFORD & AvK
 Parts Department,
 Barnack Road,
 Stamford, Lincolnshire
 PE9 2NB, UK.

Telephone: 44 (0) 1780 484000
 Fax: 44 (0) 1780 766074

or any of our subsidiary companies listed on the back cover.



SECTION 8

TECHNICAL SPECIFICATION

Input voltage (50-60Hz)	115 range 220 range 240 range 277 range	110-125v ac 200-230v ac 231-250v ac 251-290v ac (60 Hz only)	Applies to PFC E000 - 22090 (GREEN) 5VA
Input current	PF/VAR sensing Current Limit	5A CT 330mA CT	2.5VA 2.5VA
Voltage matching input		110v ac \pm 10% 5 vA nominal	
Low excitation limit input		150 V dc Max	
AVR control range (A1 A2)		\pm 3 volts dc	
Power Factor setting range (PF)		0.7 lag to 0.7 lead (see note 1)	
Remote PF setting potentiometer value		10K ohms 1 watt	
Reactive current setting range (VAR) generate/absorb		0-100% gen. current (see note 1)	
Low excitation limit range		2-8 volts dc	
Current limit range		70-100% gen. current	
Control accuracy	VAR Power Factor Voltage matching	\pm 5% (see note 2) \pm 0.05 pf \pm 2%	
Reponse time constant		4 seconds	
Generator output voltage limiting range		\pm 5% to \pm 15%	
Environmental	Vibration Relative humidity Operating temperature Storage temperature	20-100 Hz 100-2 kHz 0-60 °C -40 to +70 °C -55 to +80 °C	50 mm/s 3.3 g 95%

Note 1: Refer to generator lag/lead performance data sheets for permissible operating conditions.

Note 2: Control accuracy may drift if the CT secondary current falls below 0.5 Amps.

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