Customer: TBV Power

Project: Barry Power Station
Works Order No. C3161

Contents

1. Introduction.

This manual describes the operation and control of the diesel generator package as supplied by F.G.Wilson (Engineering) Ltd. The document has been divided into sections as detailed on the cover page.

Introduction	This gives the operator an overview of the information contained in each section as a means of identifying which section to refer to for a particular item of information.
Control Philosophy	This section gives a general description of the equipment provided and a summary of how the overall system operates.
Panel Equipment	This section includes an extensive list of the equipment within the control panel which the operator may be required to use while operating the system.
System Operation	A full description of how the system operates is contained in this section. This includes both automatic and manual operations as applicable. For automatic control it describes what the operator would see during an operation and for manual control it describes in detail how an operator would perform each control function.
Generator auxiliaries	A list of engine and alternator auxiliaries is given within this section. The power ratings and control of these items will be provided. These items include engine heaters, alternator heaters, lube oil top up systems etc as required.
Auxiliary panels	This section provides information regarding additional panels/electrical hardware within the overall package. Information on how each of these units operates is supplied and how they interface into the overall scheme.
Drawing list	A list of all relevant drawings for the project for reference.
Technical manuals	Literature on components used in the manufacture of the control panel.

2. Control Philosophy

F.G.Wilson (Engineering) Ltd. have supplied a diesel engine driven generator comprising of a ***4012TAG2 Perkins*** engine driving an ***LSA52VL9/4 Leroy Somer*** alternator. The generator has an output of *1500*KVA at *6.6*KV, *50*Hz which will produce *131.2* Amps.

Associated with the generator is a ***Three Section, Floorstanding*** control panel.

The control panel houses all the equipment required for the control and monitoring of the generator system.

An engine mounted gauge panel is also supplied to provide some local engine monitoring, emergency stop button and an easily accessible termination housing for all engine cabling.

A neutral earthing resistor enclosure is also required, it has been specially enlarged to allow mounting of the CT's.

The complete package is supplied within a container. The primary function of the generator is to start up following a momentary remote start signal. This signifies mains supply being lost and the generator will run up to normal speed and voltage. Provided certain conditions apply the breaker may be closed. Once the generator is on load it will continue to run until a remote stop signal is received which will prompt synchronisation with the restored mains supply. Once in sync the set will ramp off load and open the generator breaker. The set continues to run for a period of time to cool down before stopping.

3. Panel equipment

Metering

Generator voltmeter	Monitors the output voltage level of the generator
Generator ammeter	Monitors the current output from the alternator
Generator frequency meter	Monitors the output supply frequency of the generator
Generator kilowatt meter	Indicates the output from the generator
Engine battery voltmeter	Monitors the condition of the engine battery
Hours run meter	Indicates the total running time of the generator (non-resettable)
Generator power factor	Indicates the power factor of the output
Mains voltmeter	Monitors the voltage level of the mains supply
Mains ammeter	Monitors the current of the mains supply
LED syncscope	Used to indicate when mains and generator are synchronised

Remote monitoring

Volt free contacts are available for generator running, general alarm, control switch and VT selector switch.

Annunciator
Shutdowns (Red)

Fail to start	If the generator does not start by the completion of the three attempt start sequence, the starter circuit is locked out and the 'fail to start' LED is illuminated.
High engine temperature	Activated by an engine mounted switch which closes when the engine temperature rises above the pre-determined threshold.
Low oil pressure	An engine mounted switch will close and shutdown the generator. If the oil pressure falls too low this protection is inhibited during start up to allow the pressure to build up.
Overspeed	A magnetic pick-up on the engine, measures the speed of the flywheel. Once a certain threshold speed has been reached a relay is activated and the generator is shutdown.
Low water level	A switch mounted in the engine radiator closes when the water level in the radiator falls below the set point. A reduction in the coolant may prevent the generator achieving full load for prolonged periods of time.
Emergency stop operated/start inhibited	Activation of the emergency stop push button immediately stops the generator. The push button is active at all times and in all control modes. A start inhibit keyswitch must be in place to allow generator start up.

Generator over voltage	If the voltage at the alternator terminals rises 10% above the nominal output voltage a voltage sensing relay trips initiating a generator shutdown.
Generator under voltage	Loss of a phase of the generator supply will cause the under voltage relay to trip initiating a generator shutdown. (Normally 10% drop in volts).
Over frequency	A frequency monitoring relay trips if the alternator supply frequency rises more than 10% above the nominal output frequency.
Generator under frequency	A frequency monitoring relay trips if the alternator falls more than 10% below the nominal output frequency.
Fail to synchronise	This shutdown is only operative when the generator is in autosync mode. After the automatic synchroniser has been energised for a period of time (normally 2 minutes - adjustable) without successfully closing the generator breaker the generator is shutdown primarily, this is because the process should take less than a minute and therefore is not likely to occur after this time. It is also not recommended to run the generator off load for extended periods of time.
Reverse power	When the generator is in parallel there is the possibility of motoring the engine to prevent this condition. A reverse power relay monitors the current and trips if it senses a reverse flow causing an engine shutdown.
Overcurrent	A relay senses short circuit of the generator by measuring current on the phases.
Earth fault	Relay detects an earth fault and shuts down the generator. The monitored zone is from CT back towards the alternator.
Differential fault	Relay detects overcurrent and earth fault within the designated zone. (i.e. between the class X CT's)
Volt unbalance	Relay to detect phases being unbalanced
Neutral earth contactor fail	Annunciates that the NEC has failed either to open or close. (Contactor close when generator running and not parallel).
High winding temperature	RTD's within the alternator sense winding temperature. Transducers within the panel will switch at a certain temperature and shutdown the machine.
Low water temperature	An engine mounted switch will close and shutdown the generator on low water temperature.
High oil temperature	An engine mounted switch will close and shutdown the generator on high oil temperature.
Fuel pump trip	Overload signal from the pump contactor to show that the fuel pump has tripped out.
Lock out operated	Indication that the lockout relay has been operated and must be manually reset at the relay.

Alarms (Amber)

Generator fault	Alarm indication for a common fault occurrence initiated by all shutdown and alarm functions.
Fail to sync	This alarm is only operative when the generator is in autosync mode. After the automatic synchroniser has been energised for a period of time (2 minutes - adjustable) i.e. retransfer attempt in progress without successfully closing the mains breaker an alarm is signalled at the generator control panel.
Low battery volts	A voltage sensing relay is wired across the terminals of each of the batteries in the generator. If the battery terminal voltage falls the relay de-energises and an alarm is raised.
Not in auto	Alarm condition to state that control system is no longer in the automatic position.
Low fuel level	Alarm condition to state that the fuel level has fallen to a low level (switch by others).

Indications (Green)

Fuel on	Light on the panel to show the condition that fuel is on i.e. control relays are energised.
Alarm mute	Indication that the audible alarm has been muted (alarm mute depressed).
Test mode	Indication that currently in the test with synchronising mode .
Charger boost on	Indication that battery charger is in boost mode.

Switches

Control mode	Stop	Engine stopped-unable to start generator
	Manual	Generator controlled at FGW panel
	Auto	Generator started remotely
	Test	Generator test mode
Sync reference	Mains VT	Select to sync to mains 1
	Gen VT	Select to sync to bus
Sync mode	Manual	Select to synchronise manually (speed/volts adjust)
	Off	No synchronising permitted
	Auto	Select for automatic synchronising to take place provided all other conditions are satisfied.
Speed adjust	Raise	Increases the alternator output frequency
	Lower	Decreases the alternator output frequency
Volts adjust	Raise	Increases the alternator output voltage
	Lower	Decreases the alternator output voltage

Push-buttons

Start	Used to initiate generator start sequence in local control mode.
Stop	Used to stop the generator locally after a start initiated from the control panel.
Reset	Used to reset the control system after the initiation of an alarm or shutdown.
Lamp test	Used to test all the LED's/lamps on the panel.
Alarm mute	Used to silence the audible alarm.
Emergency stop	Used to stop the generator in all modes. Active at all times.
Gen breaker open	Opens generator breaker, active at all times and all modes.
Gen breaker close	Closes generator breaker, only if dead bus or in sync conditions apply.
Mains breaker close	Closes mains breaker provided certain conditions apply ('dead bus' or in 'sync').
Mains breaker open	Opens mains breaker. Functions at all times and in all modes.

Relays

Reverse power relay	Used to ensure that engines are not reversed powered by monitoring the direction of current flow to/from the alternator.
Check sync relay	Issues breaker close permit signal when the voltage, phase and frequency difference between the generator and the busbar are within pre-set limits. The relay includes 'dead bus' monitoring to enable breaker closure if there is no voltage present on the busbar.
Over/under voltage relays	Monitors the alternator output voltage for an increase/decrease in voltage. All three phases are monitored.
Combined over/under frequency relay	Monitors the alternator output for an increase/decrease in frequency.
Lockout relay	5 N/O and 5 N/C contacts which remain energised until the relay itself is manually reset.
Earth fault relay	Monitors the generator output for restricted earth fault.
Differential relay	Monitors area defined by the class X CT's for earth fault or overcurrent.
Overcurrent	Monitors the generator output for voltage restricted.
Voltage unbalance	Monitors the voltage for unbalance on the phases.

3.1 Bill Of Materials (Major Components)

FGW Reference	Description	Supplier
171-022	Synchroniser SPMA	Woodward
171-072	AGLC Load Controller	Woodward
171-086	Generator Load Sensor	Woodward
607-522	Sync Select Keyswitch	UK Solenoid
604-241	Volts Selector Switch	UK Solenoid
604-242	Ammeter Selector Switch	UK Solenoid
606-071/		
606-072/	Push Buttons	Telemecanique
606-073		
606-074/	Emergency Stop c/w Guard	Telemecanique
606-132		
606-134/	Illuminated Push Buttons	Telemecanique
606-135		
620-277	Hours Run Meter	ENM Company
620-698	kW Transducer	Crompton
624-193	0-200Amp Ammeter	Crompton
624-397	0-7000V Voltmeter	Crompton
624-579	0-1500kW kW Meter	Crompton
624-689	Frequency Meter 45-55Hz	Crompton
624-718	LED Syncscope	Crompton
624-727	Power Factor Meter	Crompton
626-003	Oil Temperature Gauge	VDO
626-008	Battery Volts Gauge	Equus
630-001/	Relays (11 Pin Internal Slave)	IMO
630-009		
630-123	Relay Differential MCAG34	GEC
630-335	Earth Fault Relay MCGZZ	GEC
630-337	Volt Dependant Overcurrent MCVG61	GEC
631-160	Undervolts Relay MVTU11	GEC
631-163	Overvolts Relay MVTU12	GEC
631-164	Test Block	GEC
631-385	Temperature Relay RTL602	Rayleigh
631-413	Check Sync Unit	Crompton
631-453	Over/Under Frequency Relay MFVU21-A	GEC
631-454	Reverse Power Relay MWTU11	GEC
631-455	Voltage Unbalance MVAP22	GEC
631-456	Lockout Relay MVAJ13	GEC
631-457	Voltage Transducer 256-TVLW	Crompton
632-416	24V DC Cyclic Timer	Broyce
640-143	Voltage Transformer 6600/110V 200VA	Transmag
641-232	200/1A 5P10 CT	Transmag
641-234	200/1A Class X CT	Transmag
644-033	Semaphore Lamps - Red/Green	PL Automation
652-122	Battery Charger	Computronic
660-188	Motorised Pot	Selco
694-004	24V DC Motorised Siren	RS

4. System operation

4.1 Overview

The following control switches are supplied on this particular generator control package:-

Switch 1	→	Off/Manual/Auto/Test (Control)
Switch 2	→	Off/Manual/Auto (Sync)
Switch 3	→	Mains VT/Gen VT

This section gives a more detailed description of the panel operation.

4.2 Auto Mode/Auto Sync

This section deals with the case where switch 1 is in the auto position and switch 2 is also in the auto position.

Upon mains failure the DCIS sends a remote start signal to the generator control panel. This signal is momentary and is latched by the generator control circuitry to initiate the generator to run up to speed and voltage. The generator breaker may be closed onto a dead bus.

The operator then loads the bus by closing appropriate breakers.

Generator is now on load, gen breaker closed, mains breaker open.

Following mains restoration the operator switches the VT selector to the mains VT position. (The mains breaker "Permit to close" light on the control panel must be illuminated).

The DCIS sends a momentary remote stop signal which initiates synchronisation. Once in sync the mains breaker is signalled to close.

The generator ramps down load, opens gen breaker and runs on for a period of time to allow cooldown. Once this times out the set will shutdown.

The operator then returns the VT selector to the gen VT position.

4.3 Manual Mode/Auto Sync

This section deals with the case where switch 1 is in the manual position with switch 2 remaining in the auto position.

Once the generator mode switch is in the manual position the generator can only start/stop via the pushbuttons located on the generator control panel.

Synchronisation will not take place automatically (Manual Control Mode → Breaker Manual Control).

4.4 Control Mode Off

When the control mode switch is in the off position, the generator cannot be started (the set is locked out).

The set will not be effected by the position of other switches.

4.5 Test Mode/Auto Sync

Mains on load, bus loaded, VT selector in gen VT position.

The generator must be started via the pushbuttons. The set then comes up to speed and voltage. The set then auto syncs to the mains and closes the gen breaker. The machine then ramps up to the set base load and continues running.

Operator then pushes stop button and the generator ramps down off load, opens the gen breaker, runs for a cooldown period before shutting down.

4.6 Manual Mode/Manual Sync

4.6.1 Gen Stopped, Gen Breaker Open, Mains Breaker Closed

Operator pushes start button and the generator comes up to speed and voltage.

Operator switches VT selector to gen VT position.

Operator manually syncs the generator to the mains and closes the gen breaker via the pushbutton on the control panel.

An LED syncscope, voltmeters and ammeters on the panel will assist the operator to attain synchronism.

Breaker closure out of sync is prevented at all times via a check sync unit.

Operator manually loads the generator and manually unloads via speed adjust switch.

Once the gen breaker is open the operator can push the stop button which will initiate the cool down and subsequent stopping of the generator.

4.6.2 Gen On Load, Mains Breaker Open

Upon restoration of the mains supply the operator switches VT selector to the mains VT position. Provided the permit to close contact is closed the operator can manually sync with the mains supply and close the mains breaker. The operator manually unloads the generator and opens the breaker.

Pushing the stop button will initiate cool down and stop.

4.7 Sync Off Position

With the sync selector in the Off position no synchronisation is permitted. Breakers may be opened, but can only be closed under dead bus circumstances.

5. Generator auxiliaries

Auxiliary	Rating	Operational control
Engine heater	2 x 2.5kW	Heaters automatically energised when engine stops. Additional control via integral thermostat.
Battery charger	200W	Energised when the engine is not running. Charger also de-energised during engine cranking sequence.
Alternator heater	200W	Energised when engine is not running (trace heat for anti condensation purposes).
Panel heater	240W	Anti condensation heater for control panels

The auxiliary supply required is single phase AC (220 - 240 VAC)

6. Additional panels/equipment

6.1 Gauge Panel

The engine is wired to a set mounted gauge panel. This panel also has engine monitoring gauges and an emergency stop button. The gauges include engine temperature, RPM, oil pressure and oil temperature. All cabling from the generator to the floorstanding control panel are routed via this gauge panel This should allow more convenient cable installation.

6.2 Electronic Governor

The controller for the electronic governor is also engine mounted. The interfacing required is carried out via the engine panel to the control panel.

6.3 Automatic Voltage Regulator

The AVR is door mounted on the generator control panel it is model No. R610.

6.4 Neutral Earthing Resistor Panel

This panel is mounted within the control room of the container in front of the generator control panel. The neutral star point of the set is made within an oversized power chamber within the NER enclosure. This allows CT's to be mounted within the enclosure.

6.5 Distribution Box

A distribution box is situated close to where the control cables come into the container. The board requires a 220/240V single phase auxiliary supply.

7. Drawing list

Drawing Number	Drawing Title
D22017	Wiring diagram of engine gauge panel
D21936	Wiring diagram of DC control
D21937	Wiring diagram of AC control
D21938	Wiring diagram of protection relays
D21939	Wiring diagram of CT/VT/AVR connections
D22032	Wiring diagram of common control
MDA1766	General arrangement of the floorstanding control panel

8. Technical Manuals.

1. R610 AVR (Leroy Somer)
2. MSA52VL9/4 (Leroy Somer)
3. Proact II Governor (Woodward)
4. Load Sharing Module (Woodward)
5. Automatic Generator Loading Control (AGLC) (Woodward)
6. SPM-A Synchroniser (Woodward)
7. Check Sync Unit (Crompton)
8. Reverse Power Relay (GEC)
9. Over Volts Unit (GEC)
10. Over/Under Frequency Unit (GEC)
11. Under Volts Relay (GEC)
12. Lockout Relay (GEC)
13. Voltage Unbalance (GEC)
14. Differential Protection Relay (GEC)
15. Earth Fault Relay (GEC)
16. Voltage Restrained Overcurrent (GEC)

APPENDIX 1

CALCULATING KNEE POINT VOLTAGE FOR DIFFERENTIAL CT

(SEE SHEET)

APPENDIX 2

PROPOSED SETTINGS FOR PROTECTION RELAYS

(SEE SHEET)

1. Calculating Knee Point Voltage For Differential CT (Vk)

1.1 The following formulae are required to permit a knee point voltage to be calculated.

$$V_k \geq 2 I_F (R_S + R_P)$$

$$I_e = \frac{I_S - I_r}{n}$$

$$R_{sr} = \frac{Vk/2}{I_r}$$

Where,

I_F	-	Fault Current
R_S	-	Secondary Winding Resistance
R_P	-	Lead Resistance
I_e	-	Maximum Excitation Current
n	-	2 (For Differential)
I_R	-	Relay Setting (In Secondary Amps)

From the alternator data sheet the following figures can be found:-

X''_D = 10.1%

= 0.101 PU

Base = Rated kVA

= 1500 kVA

$$\frac{1500}{0.101 \times 3 \times 6.6} \approx 1300 \text{ Amps}$$

$I_f = If/_N$ N = CT Ratio

$I_f = 1300/_{200}$

= 6.5 Amps

$\therefore$ Vk $\geq$ 2 x 6.5 ($R_{CT} + R_L$)

To Calculate R_P (Lead Resistance)

Need to know:-

1. Length of loop between differential CT's.
2. OHMIC value for size of cable.

Assume length of loop = 20m

Volts drop of 4.0mm^2 cable is given as; 11mV/M/A

Tank case where I = 1 Amp

V	=	IR
0.011	=	R_P/m
For 20m R_P	=	0.22 Ω

$\therefore$ Now know R_P (Lead Resistance)

$\therefore$ Vk $\geq$ 13 (R_{CT} + 0.22)

For Stablising Resistance, R_{ST},

$$R_{ST} = \frac{Vk/2 - VA/Ir}{Ir}$$

Where, VA = Burden of MCAG34

= 1 (From Data Sheet)

Ir = Setting Current

Propose use 10% - 40% Range

CT Secondary = 1A

$\therefore$ Ir = 0.1 - 0.4A

∴ At 10% Calculate Vk (Standard R_{ST} = 220Ω)

$$220 = \frac{Vk/2 - 1/0.1}{0.1}$$

Vk = 64V

At 40% Ir = 0.4

$$220 = \frac{Vk/2 - 1/0.4}{0.4}$$

Vk = 181V

∴ Differential CT should have 'Knee Point' Voltage of at least 181V

Class X 200/1 Amp CT

2. Proposed Settings For Protection Relays

Time delayed earth fault MCGG22

Setting Range:

Is = 5% - 240% (0.05-2.4A)

in 5% Steps

Proposed Setting:

5% (200/1 CT gives fault current of 10A in the neutral)

FOR 0.1 s

Voltage controlled overcurrent MCVG61

This relay should be co-ordinated with other on site protection to give proper discrimination.

Time delayed over voltage MVTU12

Setting Range:

Volts 105 - 182.5V

in 2.5V Steps

Time 0.1 - 9.95

in 0.1s Steps

Proposed Setting:

120V for 1 second

Time delayed under voltage MVTU11

Setting Range:

Volts 62 - 108.5V

in 1.5V Steps

Time 0.1 - 9.95s

in 0.1s Steps

Proposed Setting:

100V for 1 Second

Time delayed reverse power relay MWTU11

Setting Range:

Power 1% - 32.5% in 0.5% Steps

Time 0.25Sec - 32 Sec in 0.25 Sec Steps

Proposed Setting:

8% for 5 Sec

Over/Under frequency

Setting Range:

10 Hz - 500 Hz

Proposed Setting:

Over frequency - 55Hz

Under frequency - 45Hz

Differential protection MCAG34

Proposed Current Setting: 10% - 40%

Class X CT Calculation refer to Section 1

Lock out relay MVAJ13

Hand reset

5 Open 5 Close