Designer's Reference Handbook

PPU Power Management (PPM)

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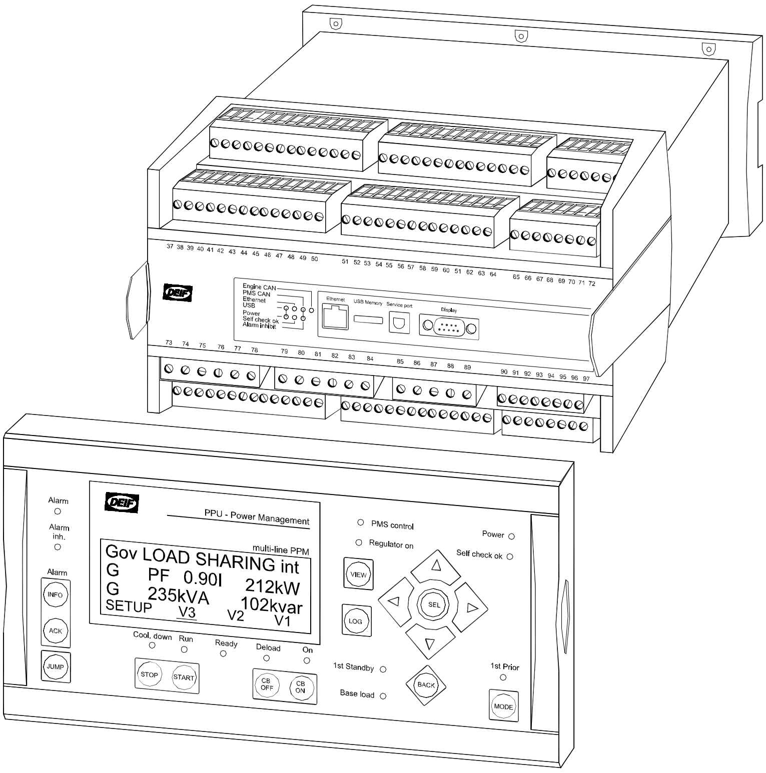

- *Functional descriptions*
- *Power Management*
- *Internal communication*
- *External communication*

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1. About this document

This document is the Designer's Reference Handbook for DEIF's PPU Power Management system PPM. The document mainly includes functional descriptions for diesel, shaft and bus tie generators, PMS and technical information about internal and external communication.

The general purpose of the Designer's Reference Handbook is to offer background and technical information about the functionality of the PPM system.

Please make sure that you read this manual before starting to work with the PPM system. Failure to do this could result in damaging the equipment or even worse, injury of personnel.

Intended users

This handbook is mainly intended for the panel builder designer in charge. On the basis of this document, the panel builder designer will be able to achieve in-depth technical knowledge of the functionality of the PPM system.

Contents/overall structure

This document is divided into chapters, and in order to make the structure simple and easy to use, each chapter will begin from the top of a new page.

Definitions

Throughout this document a number of notes and warnings will be presented. To ensure that these are noticed, they will be highlighted in order to separate them from the general text.

Notes

The notes provide general information which will be helpful for the reader to bear in mind.

Warnings

The warnings indicate a potentially dangerous situation which could result in death, personal injury or damaged equipment, if certain guidelines are not followed.

2. Warnings and legal information

Legal information and responsibility

DEIF takes no responsibility for installation or operation of the generator set. If there is any doubt about how to install or operate the generator set controlled by the unit, the company responsible for the installation or the operation of the set must be contacted.

The units are not to be opened by unauthorised personnel. If opened anyway, the warranty will be lost.

Electrostatic discharge awareness

Sufficient care must be taken to protect the terminals against static discharges during the installation. Once the unit is installed and connected, these precautions are no longer necessary.

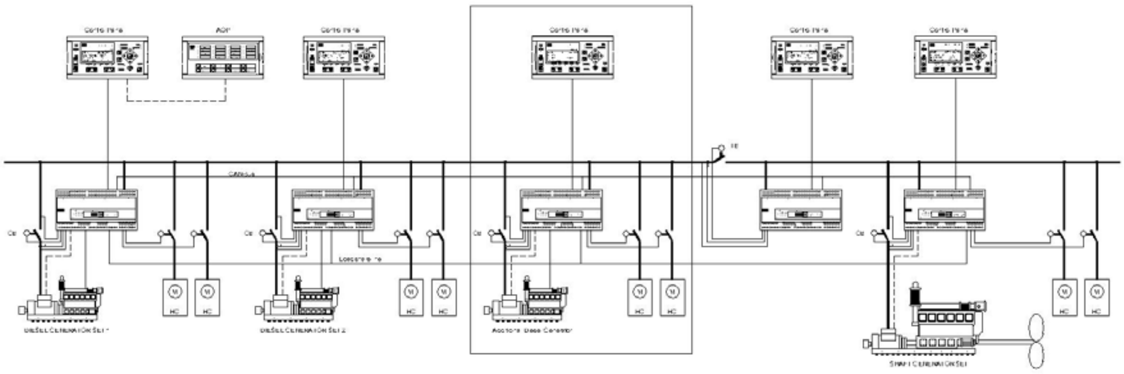
Safety issues

Installing the unit implies work with dangerous currents and voltages. Therefore, the installation should only be carried out by authorised personnel who understand the risks involved in working with live electrical equipment.

Be aware of the hazardous live currents and voltages. Do not touch any AC measurement inputs as this could lead to injury or death.

3. General product information

The *PPU Power Management* is a standard power management system for marine applications. The system carries out **generator control**, **supervision** and **protection** functions. One or more units include a separate processor for the power management functions.



The internal communication between the units is carried out via internal CAN bus. This CAN bus is intended for DEIF use only and cannot be connected to other external CAN bus systems.

The external communication to an alarm and monitoring system can be performed via

- RS485 modbus RTU,
- Ethernet TCP/IP modbus

The separate power management processor has a built-in webserver which enables monitoring of status signals and measuring of values and alarms from any PC connected to a network (password protected).

Standard systems

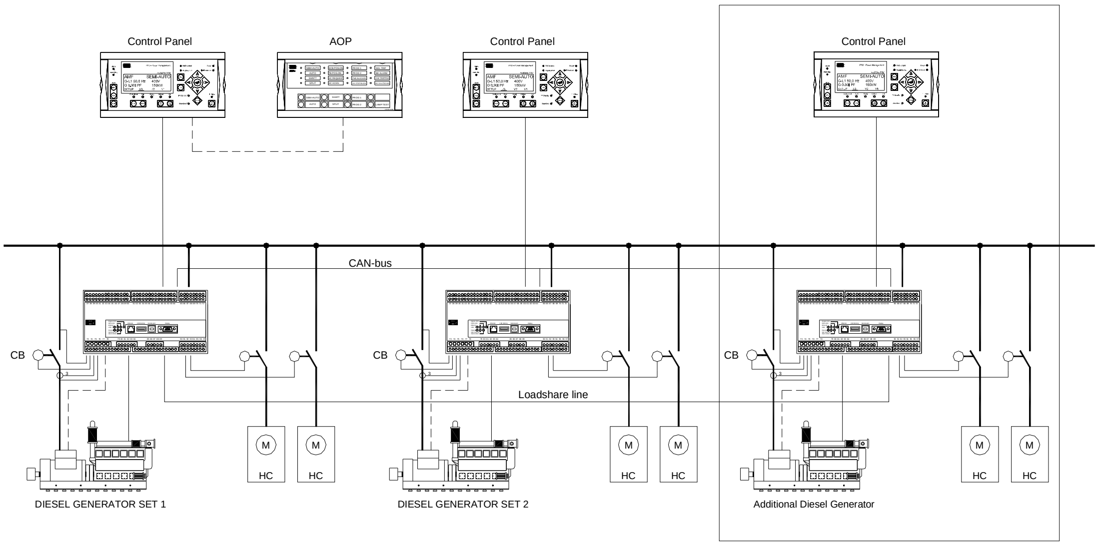
The following *PPU Power Management* systems are available as **basic** packages:

System name	System overview	Remarks
SYSTEM 01	DG1 + DG2 + DGn	Min. 2 DGs/system Max. 8 DGs/system
SYSTEM 02a (shaft) SYSTEM 02b (shore)	DG1 + DG2 + DGn + SG DG1 + DG2 + DGn + SC	Short time parallel operation between DG and SG/SC Min. 2 DGs and 1 SG/SC Max. 8 DGs and 1 SG/SC
SYSTEM 03	DG1 + DG2 + DGn + SG + TB	Short time parallel operation between DG and SG Including separate SPLIT busbar mode Min. 2 DGs, 1 SG and 1 TB Max. 8 DGs, 1 SG and 1 TB

System 01

The system 01 basic package has been designed for applications consisting of *minimum two diesel* generators and *maximum eight diesel* generators on one busbar.

The available plant modes are SEMI-AUTO and AUTO. In SEMI-AUTO plant mode the push-buttons on the display unit for START, STOP, CB ON and CB OFF are enabled. In AUTO plant mode the diesel generators carry out the load dependent START/STOP function, while the push-buttons on the display unit are inactive.



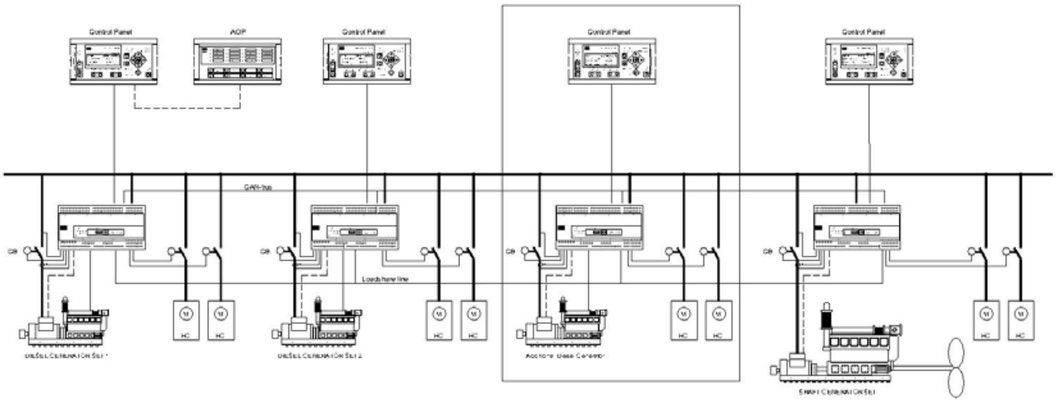
Common functions (total plant)

- Plant modes: - SEMI-AUTO
  - AUTO
- User-programmable start priority
- Automatic start priority control concerning running hours
- Load dependent start/stop function incl.:
  - transmission of PMS start/stop commands
  - safety start of stand-by generator sets due to expected stop of a running generator set
  - transfer of PMS start command in case of failed engagement of the generator
- Blackout function:
  - common blackout detection and subsequently blackout start of one/two diesel generator set(s), adjustable by a set point
  - local blackout detection and subsequently blackout start of the next available diesel generator in case of “missing master” unit
- Symmetrical or asymmetrical load sharing
- Conditional connection of two heavy consumers per generator unit
- Supervision of a shore connection breaker position
- Supervision of a bus coupler position

For further information regarding the power management functions, please see chapter 9.

System 02 (shaft)

The system 02 (shaft) basic package has been designed for applications consisting of two to eight diesel generators and one shaft generator on one busbar. The shaft generator has no frequency control and is only used for short time parallel operation. In addition to the plant modes SEMI-AUTO and AUTO from system 01, system 02 (shaft) can handle the plant mode _SHAFT_. Whenever the _SHAFT plant mode_ is selected, the system will synchronise the shaft generator breaker and stop the diesel generators automatically. When AUTO plant mode is selected, the diesel generator(s) will start up and connect to the busbar (regarding their priority), deload the shaft generator and open the shaft generator breaker.



(Only short time parallel running between SG and DG)

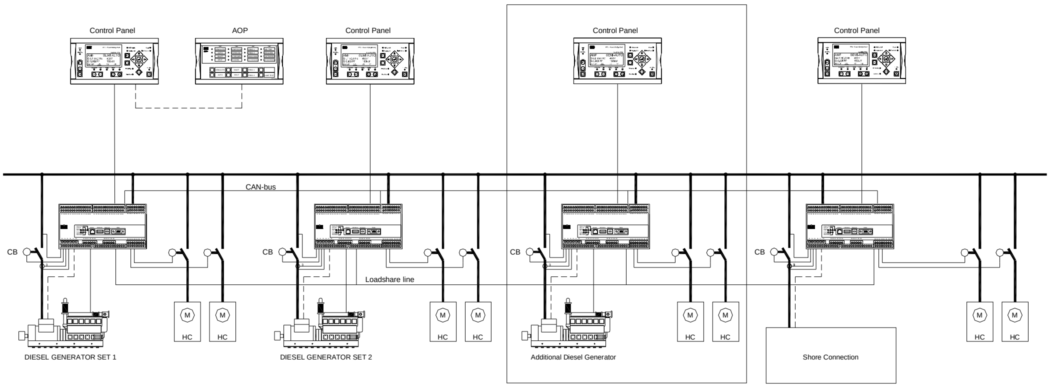
Common functions (total plant)

- Plant modes: - SEMI-AUTO
  - AUTO
  - SHAFT
- User-programmable start priority
- Automatic start priority control concerning running hours
- Load dependent start/stop function incl.:
  - transmission of PMS start/stop commands
  - safety start of stand-by generator sets due to expected stop of a running generator set
  - transfer of PMS start command in case of failed engagement of the generator
- Blackout function:
  - common blackout detection and subsequently blackout start of one/two diesel generator set(s), adjustable by a set point
  - local blackout detection and subsequently blackout start of the next available diesel generator in case of "missing master" unit
- Symmetrical or asymmetrical load sharing
- Conditional connection of two heavy consumers per generator unit
- Supervision of a shore connection breaker position
- Supervision of a bus coupler position
- Control and supervision of _one_ shaft generator

For further information regarding the power management functions, please see chapter 9.

System 02 (shore)

The system 02 (shore) basic package has been designed for applications consisting of two to eight diesel generators and one synchronised shore connection on one busbar. The shore connection handling is only used for short time parallel operation. In addition to the plant modes SEMI-AUTO and AUTO from system 01, system 02 (shore) can handle the plant mode _SHORE_. Whenever the _SHORE plant mode_ is selected, the system will synchronise the shore connection breaker and stop the diesel generators automatically. When AUTO plant mode is selected, the diesel generator(s) will start up and connect to the busbar (regarding their priority), deload shore connection breaker and open the shore connection breaker.



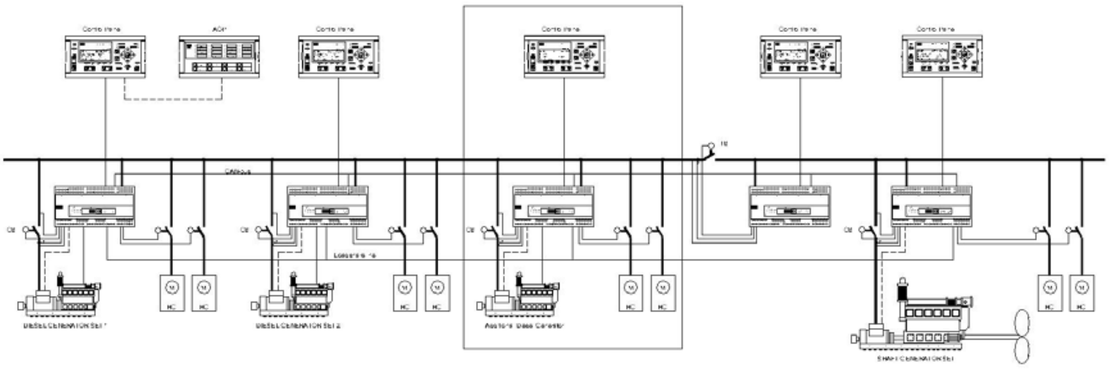
Common functions (total plant)

- Plant modes: - SEMI-AUTO
  - AUTO
  - SHORE
- User-programmable start priority
- Automatic start priority control concerning running hours
- Load dependent start/stop function incl.:
  - transmission of PMS start/stop commands
  - safety start of stand-by generator sets due to expected stop of a running generator set
  - transfer of PMS start command in case of failed engagement of the generator
- Blackout function:
  - common blackout detection and subsequently blackout start of one/two diesel generator set(s), adjustable by a set point
  - local blackout detection and subsequently blackout start of the next available diesel generator in case of "missing master" unit
- Symmetrical or asymmetrical load sharing
- Conditional connection of two heavy consumers per generator unit
- Supervision of a bus coupler position
- Control and supervision of _one_ shore connection breaker

For further information regarding the power management functions, please see chapter 9.

System 03

Compared to system 02, system 03 can also handle one automatic *bus tie breaker*. The bus tie breaker must always be placed between the diesel generators and the shaft generator. In addition to the plant modes of system 02 (shaft), system 03 is equipped with a *SPLIT plant mode*. When selecting the *SPLIT plant mode* coming from the AUTO plant mode, the system will synchronise the shaft generator and open the bus tie breaker. When selecting the *SPLIT plant mode* coming from the SHAFT plant mode, the diesel generator(s) will start up and synchronise to the busbar. After short time parallel operation with the shaft generator the bus tie breaker will open.



(*Only short time parallel running between SG and DG*)

Common functions (total plant)

- Plant modes: - SEMI-AUTO
- AUTO
- SHAFT
- SPLIT
- User-programmable start priority
- Automatic start priority control concerning running hours
- Load dependent start/stop function incl.:
  - transmission of PMS start/stop commands
  - safety start of stand-by generator sets due to expected stop of a running generator set
  - transfer of PMS start command in case of failed engagement of the generator
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- Symmetrical or asymmetrical load sharing
- Conditional connection of two heavy consumers per generator unit
- Supervision of a shore connection breaker position
- Supervision of a bus coupler position
- Control and supervision of *one* shaft generator
- Control and supervision of *one* bus tie breaker

For further information regarding the power management functions, please see chapter 9.

4. Common functions

Fail classes

All activated alarms must be configured with a fail class. The fail classes define the category of the alarms and the subsequent alarm action.

Eight different fail classes can be used. The tables below illustrate the action of each fail class when the engine is running or stopped.

Diesel generator

Action / Fail class	PMS alarm relay & alarm display	Block start & synch.	Start next stand-by DG (auto mode)	Trip of CB	Cooling-down	Stop	Block for blackout start
1 Warning	X						
2 DG prewarning	X	X	X		X	X	
3 Block of operation	X	X					
4 Trip of breaker	X	X		X			
5 Trip + STOP	X	X		X	X	X	
6 Shutdown	X	X		X		X	
7 CB short	X	X		X			(X)
8 Sys. alarm	X	X					

The table illustrates the action of the fail classes. If, for instance, an alarm has been configured with the 'shutdown' fail class, the following actions occur:

- The alarm will be displayed in the alarm info screen
- The generator breaker will open instantly
- The generator is stopped instantly
- The generator cannot be started

The fail class "DG prewarning" will only deload the gen-set before opening the breaker if other generators are available for start.

Fail class configuration

The fail class can be selected for each alarm function either via the display or the PC software.

To change the fail class via the PC software, the alarm function to be configured must be selected. Select the desired fail class in the fail class roll-down panel.

An active busbar alarm (FC Warning) will start up the next stand-by diesel generator to reduce a possible blackout time.

An active short circuit alarm can block for any blackout start depending on the programmed set point under the power management values.

Shaft generator

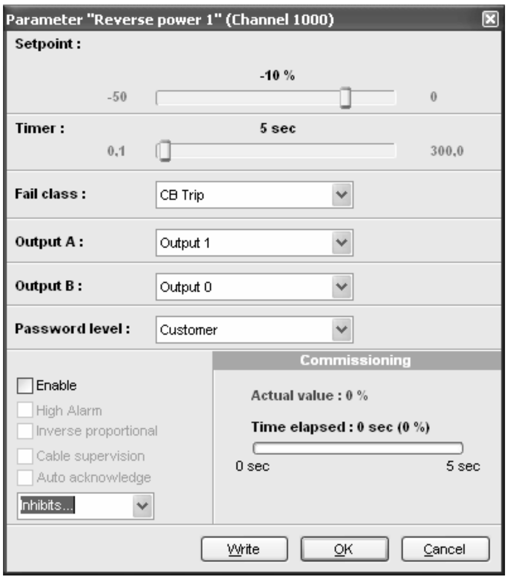
Action / Fail class	PMS alarm relay & alarm display	Block synchronisation	Trip of CB	Return to auto mode	Block for blackout start
1 Warning	X				
2 DG prewarning	X	X		X	
3 Block of operation	X	X		X	
4 Trip of breaker	X	X	X	X	
5 Trip + STOP	X	X	X	X	
6 Shutdown	X	X	X	X	
7 CB short	X	X	X	X	(X)
8 Sys. alarm	X	X		X	

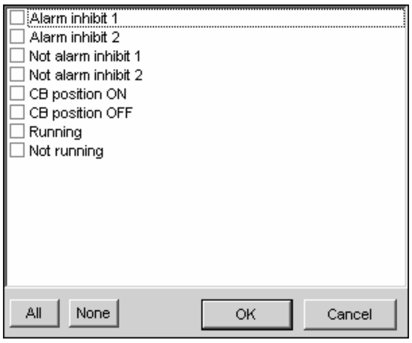
Bus tie breaker

Action / Fail class	PMS alarm relay & alarm display	Block synchronisation	Trip of CB	Return to auto mode	Block for blackout closure
1 Warning	X				
2 DG prewarning	X	X			
3 Block of operation	X	X		X	
4 Trip of breaker	X	X	X	X	
5 Trip + STOP	X	X	X	X	
6 Shutdown	X	X	X	X	
7 CB short	X	X	X	X	(X)
8 Sys. alarm	X	X		X	

Inhibit of alarms

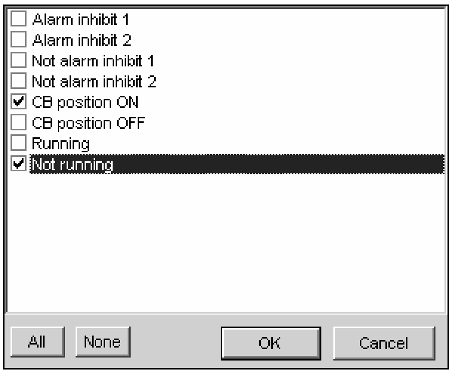
In order to select when the alarms are to be active, there is a configurable inhibit setting for every alarm. The inhibit functionality is only available via the PC utility software. For every alarm there is a drop-down window where it is possible to select which signals that have to be present in order to inhibit the alarm.





Function	Description
Alarm inhibit 1	The binary input Alarm inhibit located on terminal 50 is activated. In this case, the terminal 50 input must be selected for this
Not alarm inhibit 1	The binary input Alarm inhibit located on terminal 50 is NOT activated. In this case, the terminal 50 input must be selected for this function by using the Multi-line 2 Utility Software (I/O settings menu).
Alarm inhibit 2	The binary input Alarm inhibit located on terminal 51 is activated. In this case, the terminal 51 input must be selected for this function by using the Multi-line 2 Utility Software (I/O settings menu).
Not alarm inhibit 2	The binary input Alarm inhibit located on terminal 51 is NOT activated. In this case, the terminal 51 input must be selected for this function by using the Multi-line 2 Utility Software (I/O settings menu).
Running	The generator has been detected as running
Not running	The generator has been detected as not running

Inhibit of the alarm is active as long as one of the selected inhibit functions are active.



In this example inhibit is set to *Not running* and *CB position ON*. Here the alarm will be active when the generator has started. When the generator has been synchronised to the busbar then the alarm has been disabled again.

The tie breaker unit has no running detection that can be configured, so the only inhibit functions are the binary input and the CB position.

The alarm inhibit 1 function on the shaft generator unit will also activate the power take home mode (PTH), where the shaft generator is running as motor.

Supervision and protection

Diesel generator protection

The standard protection functions in all diesel generator units are:

- Undervoltage (3 levels)
- Overvoltage (2 levels)
- Underfrequency (3 levels)
- Overfrequency (3 levels)
- Reverse power (2 levels, inverse or definite characteristic)
- Overcurrent (4 levels, definite characteristic)
- Overcurrent (1 level, inverse characteristic)
- Fast overcurrent protection (2 levels)
- Overload (5 levels)
- Current/voltage unbalance
- Loss of excitation and overexcitation

Shaft generator protection

The standard protection functions in all diesel generator units are:

- Undervoltage (3 levels)
- Overvoltage (2 levels)
- Underfrequency (3 levels)
- Overfrequency (3 levels)
- Reverse power (2 levels, inverse or definite characteristic)
- Overcurrent (4 levels, definite characteristic)
- Overcurrent (1 level, inverse characteristic)
- Fast overcurrent protection (2 levels)
- Overload (5 levels)
- Current/voltage unbalance

Bus tie breaker protection

The standard protection functions for the bus tie breaker unit are:

- Overcurrent (4 levels, definite characteristic)
- Overcurrent (1 level, inverse characteristic)
- Fast overcurrent protection (2 levels)
- High overcurrent protection (2 levels)
- Overload (5 levels)

Reverse power

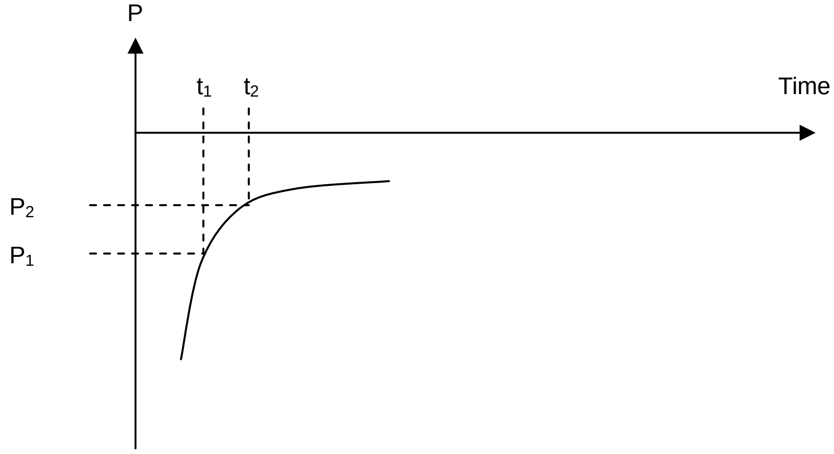
Generator reverse power protection, ANSI code 32

Reverse power settings relate to nominal power setting.

Inverse characteristic

When the set point is exceeded, the energy going through the breaker is calculated according to the set point and the time delay. The maximum energy will never be exceeded, so if the reverse power increases, the time delay will decrease and vice versa.

$$P_1 \times t_1 = P_2 \times t_2$$

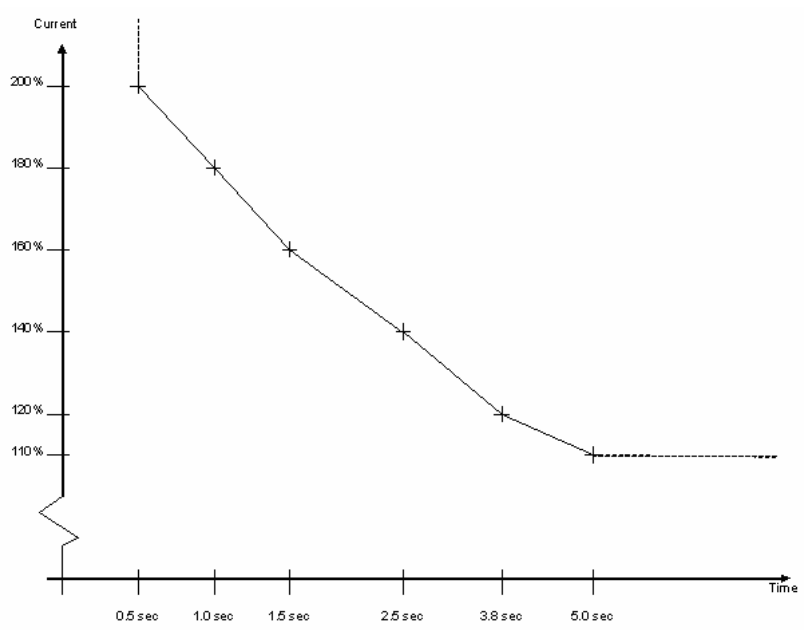


The diagram shows that at the reverse power level P1 the alarm will occur after the time t_1, and at the reverse power level P2 the alarm will occur after the time t_2.

Overcurrent (inverse)

Generator overcurrent protection. ANSI code 50/51

Settings relate to nominal generator current.



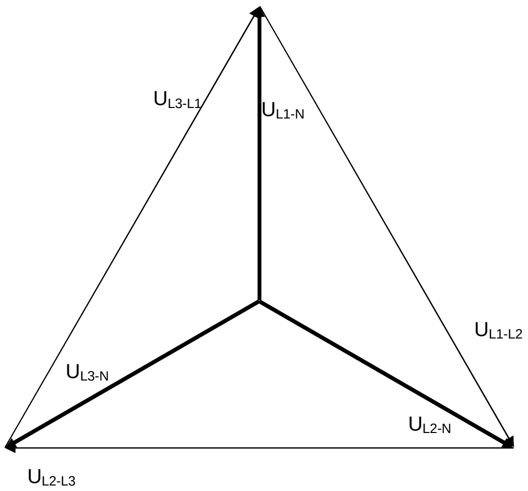
Generator voltage

Generator voltage protection, ANSI code 27/59

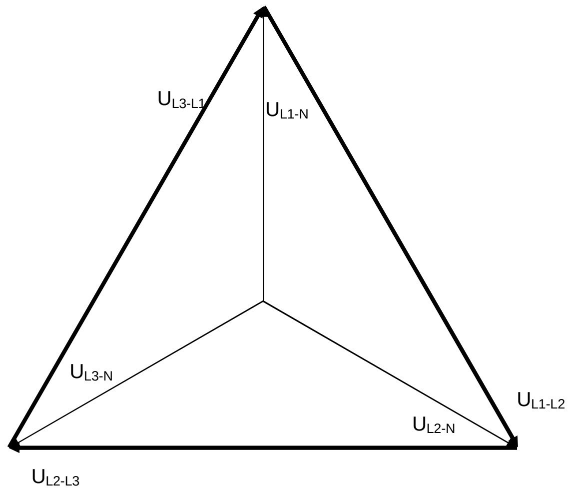
Settings relate to nominal generator voltage.

If the voltage alarms must work based on phase-neutral measurements it can be adjusted in the menu system. Either phase-phase voltages or phase-neutral voltages will be used for the alarm monitoring.

Phase - neutral



Phase - phase



It can be seen in the vector diagram below that the difference in percent for the phase-neutral voltage and the phase-phase voltage is not the similar value at an error situation. The table shows the actual measurements at a 10% undervoltage situation in a 400/230 volts system.

	Phase-neutral	Phase-phase
Nominal voltage	400/230	400/230
Voltage, 10% error	380/207	360/185

It shows that the alarm will occur at two different voltage levels, even though the alarm set point in both cases is 10%. The example below is from a 400V AC system. It shows that the phase-neutral voltage must change 20% when the phase-phase voltage changes 40 volts - 10%.

Example:

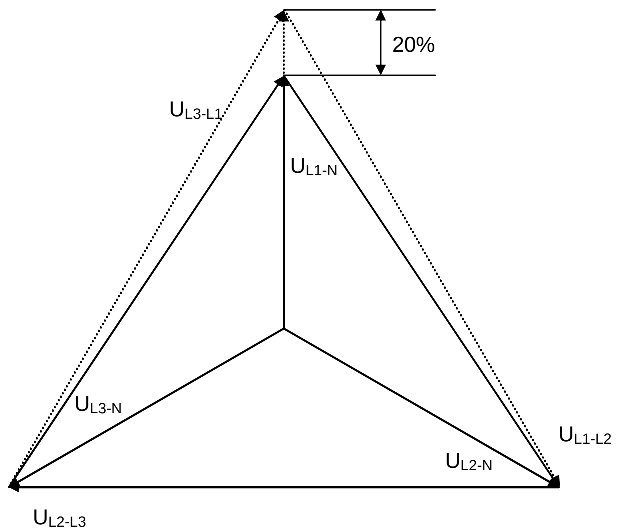
U_{NOM} = 400/230V AC

Error situation:

U_{L1L2} = 360V AC
U_{L3L1} = 360V AC

U_{L1-N} = 185V AC

ΔU_{PH-N} = 20%



Generator frequency

Generator frequency protection, ANSI code 81
Settings relate to nominal generator frequency.

Generator overload

Generator overload protection, ANSI code 32
Settings relate to nominal power setting.

Generator current unbalance

Generator current unbalance protection, ANSI code 46
Settings relate to nominal generator current.

Generator voltage unbalance

Generator voltage unbalance protection, ANSI code 47
Settings relate to nominal generator voltage (setting 6004).

Generator reactive power input

Generator reactive power import (loss of excitation) protection, ANSI code 32
Settings relate to nominal generator power kW (setting 6002).

Generator reactive export

Generator reactive export (overexcitation) protection, ANSI code 32
Settings relate to nominal generator power kW (setting 6002).

Busbar protection

The standard protection functions in all units are:

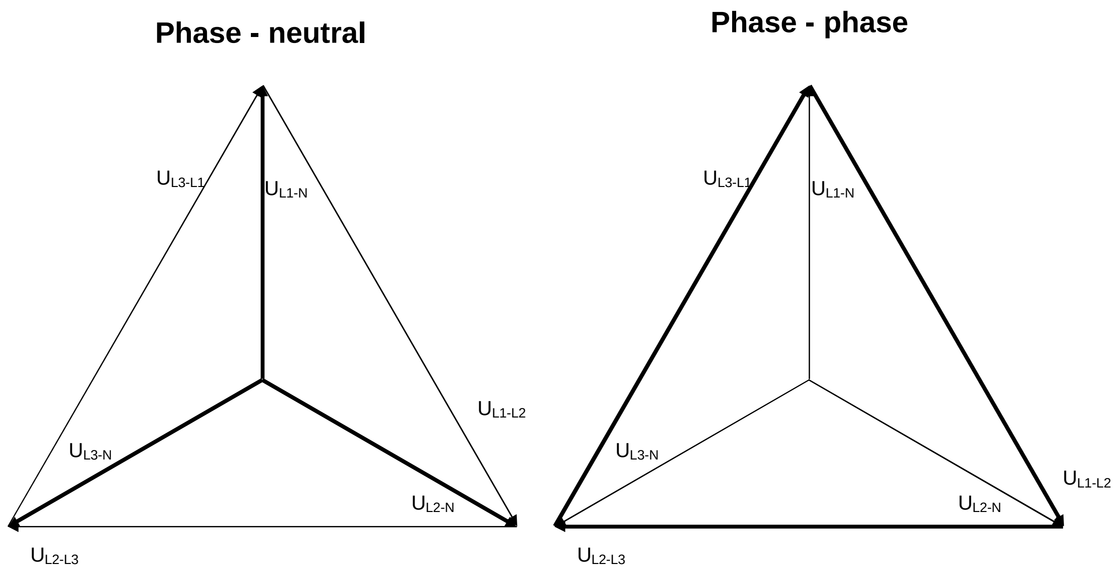
- Undervoltage
- Overvoltage
- Underfrequency
- Overfrequency

Busbar voltage

Busbar voltage protection, ANSI code 27/59

Voltage selections relate to phase-phase/phase-neutral.

If the voltage alarms must work based on phase-neutral measurements it can be adjusted in the menu system. Either phase-phase voltages or phase-neutral voltages will be used for the alarm monitoring.



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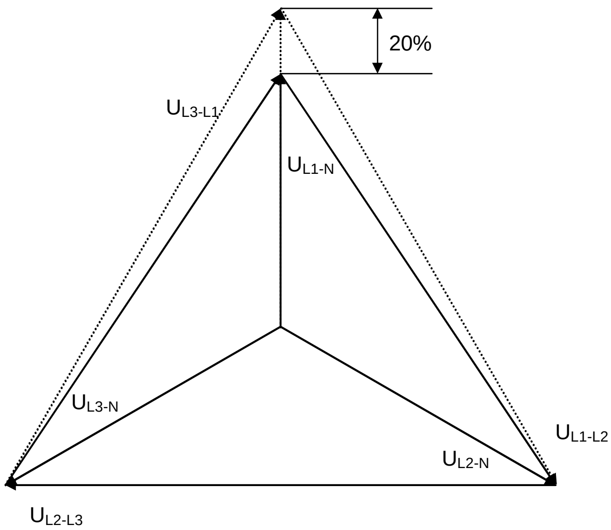
ΔU_{PH-N} = 20%



Busbar frequency

Busbar frequency protection, ANSI code 81
Frequency settings relate to nominal frequency setting.

General setup

The general setup describes the general settings for each generator unit in the PPM system.

Transformer gen./bus

If no voltage transformer is present, the primary and secondary side values are set to generator nominal value.

Date and time (internal clock) setting

The date and time can easily be synchronised with the present time and date from the utility software.

Counters

The settings below (except kWh) are offset values that need to be adjusted at the commissioning if the display is used for reading the values. A breaker operation is counted each time the breaker closes.

The setting 'Reset kWh counter' resets the value of the produced kWh.

Generator ready

The 'Generator ready' is intended for sending a binary ON/OFF signal to a monitoring system, indicating if the generator set is available for the system or not.

The 'Generator available' output will be ON if:

- There are no alarms blocking start or synchronising
- The generator set is in PMS control (term. 27)
- The input 'Ready for operation' (term. 115) is set.

The relay used for 'Generator ready' indication must be set to 'Limit' function.

In order not to have a 'Generator ready' alarm, both the A and B relay output should be set to the same 'Limit' relay.

Run status relay output

The run status output is intended for sending a binary ON/OFF signal to a control/monitoring system, indicating that the diesel engine is running.

The relay used for 'Run status' indication must be set to 'Limit' function.

In order not to have a 'Run status' alarm, both the A and B relay output should be set to the same 'Limit' relay.

f/U OK/failure

The f/U OK is used to detect when a started generator is ready for synchronisation. When the voltage and the frequency are within the window defined by blackout synchronisation settings, the synchronisation will start.

If the frequency or voltages are outside the window after the running detection has defined the generator as running, a warning message will show in the display.

Configurable alarms input

The unit has several free configurable binary inputs that can be configured as alarm inputs.

The inputs can be programmed with the following fail classes:

(1) Warning = Warning
(2) DG pre. w. = DG prewarning/safety stop
(3) Block = Block of operation
(4) Trip CB = Trip of circuit breaker
(5) Trip + STOP = Trip of CB and stop of engine (incl. cooling down)
(6) Shutdown = Trip of CB and stop of engine (without cooling down)
(7) CB short = Trip of circuit breaker and blocking for blackout start (adjustable)
(8) Sys. alarm = The unit will be forced to be under switchboard (SWBD) control

Input overview

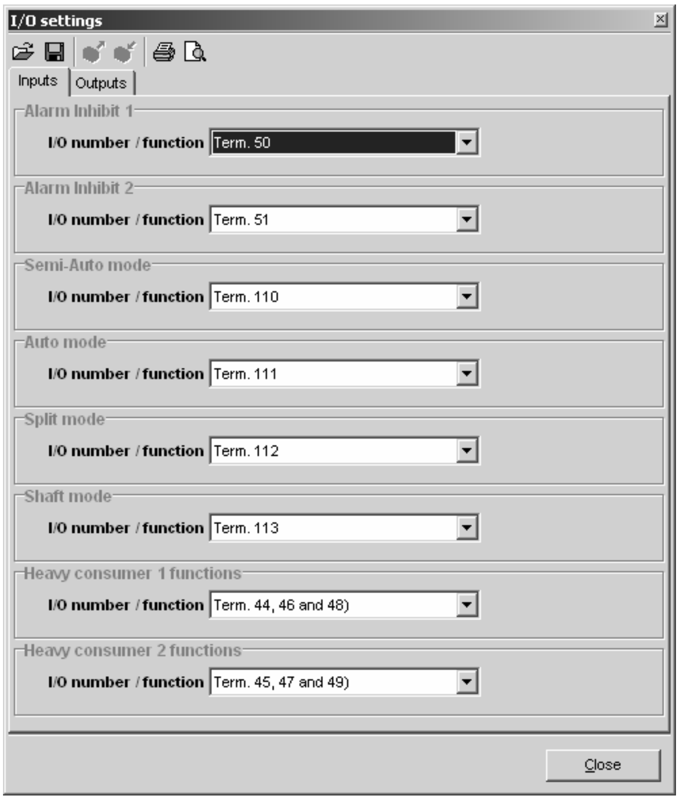
The table shows the available binary inputs. The optional binary inputs require additional hardware as option M16.

Term.	DGM	DG	SG
23	Configurable	Configurable	Configurable
24	Configurable	Configurable	Configurable
25	Shore connection position OFF (always activated in system 2 shore)	Configurable	Configurable
26	Forced SWBD	Configurable	Configurable
27	PMS control	PMS control	PMS control
43	Blackout	Blackout	Configurable
44	HC 1 request/configurable	HC 1 request/configurable	HC 1 request/configurable
45	HC 2 request/configurable	HC 2 request/configurable	HC 2 request/configurable
46	HC 1 connected/configurable	HC 1 connected/configurable	HC 1 connected/configurable
47	HC 2 connected/configurable	HC 2 connected/configurable	HC 2 connected/configurable
48	HC 1 fixed load/configurable	HC 1 fixed load/configurable	HC 1 fixed load/configurable
49	HC 2 fixed load/configurable	HC 2 fixed load/configurable	HC 2 fixed load/configurable
50	Alarm inhibit 1/configurable	Alarm inhibit 1/configurable	Alarm inhibit 1/configurable
51	Alarm inhibit 2/configurable	Alarm inhibit 2/configurable	Alarm inhibit 2/configurable
52	Configurable	Configurable	Configurable
53	Load dependent stop block	Configurable	Configurable
54	CB open	CB open	CB open
55	CB closed	CB closed	CB closed
90	Option M16/Configurable	Option M16/Configurable	Option M16/Configurable
91	Option M16/Configurable	Option M16/Configurable	Option M16/Configurable
92	Option M16/Configurable	Option M16/Configurable	Option M16/Configurable
93	Option M16/Configurable	Option M16/Configurable	Option M16/Configurable
94	Option M16/Configurable	Option M16/Configurable	Option M16/Configurable
95	Option M16/Configurable	Option M16/Configurable	Option M16/Configurable
96	Option M16/Configurable	Option M16/Configurable	Option M16/Configurable
104	Configurable	Configurable	Configurable
105	Configurable	Configurable	Configurable
106	Configurable	Configurable	Configurable
110	Configurable/Semi-auto mode	Configurable	Configurable

111	Configurable/Auto mode	Configurable	Configurable
112	Configurable/Shaft (Shore) mode	Configurable	Configurable
113	Configurable/Split mode	Configurable	Configurable
114	Emergency stop	Emergency stop	Emergency stop
115	Ready for operation	Ready for operation	Ready for operation
116	Running feedback	Running feedback	Running feedback
117	Remote start	Remote start	Configurable
118	Remote stop	Remote stop	Configurable

Configuration of the inputs by means of the utility software

The eight below inputs are selectable from the utility software. From each of them, you can select to use them at their usual and respective terminals or not to use them.



Battery voltage supervision

The unit has a supervision of the battery/supply voltage connected on terminal 1-2. The unit is able to work within a voltage range of 8V to 32V. If the voltage disappears, the undervoltage alarm is not able to react. In this case the status relay on terminal 2-3 will open in order to indicate that the unit is not in function.

Relay output

The relay 0 is a virtual relay (R0 in the setup menus).

Configured as 'Alarm', the alarms will be displayed in the alarm info window as long as the alarm is present and unacknowledged. The horn output will be closed until the alarm has been acknowledged. When configured as 'Alarm/sync. Block', the alarms will be displayed in the alarm info window as long as the alarm is present and unacknowledged. Furthermore it blocks the synchronising function for as long as the alarm condition is active. The horn output will be closed until the alarm has been acknowledged.

Relay configuration

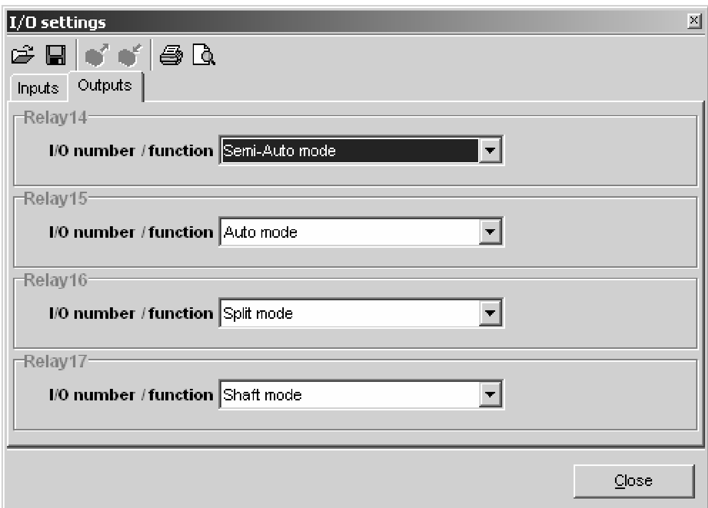
The relays below cannot be configured to any alarm:

- Relay synchronisation, terminal 17/18/19
- Status relay, terminal 3/4

Be aware that relay 4 is used as 'Breaker open' relay and the alarms configured to this relay will also open the breaker.

Configuration of the relays 14 to 17 by means of the utility software (M18 option)

The four below outputs are selectable from the utility software. From each of them, you can select to use them as alarm or limit relays or to use them for exporting a mode status information (semi-auto, auto, split or shaft (shore)).



Relay functionality

Each relay can be used with one of the following functions:

Function	Description
Alarm	The relay is activated until the alarm that caused the activation is acknowledged and gone. Alarm LED is flashing or constant
Alarm + sync. block	The relay is activated until the alarm that caused the activation is acknowledged and gone. When the relay is activated, the synchronisation is blocked but the regulation is still on
Limit	The relay will activate at the limit set point. No alarm will appear. After the condition activating this relay has returned to normal, the relay will deactivate when the 'Off delay' has expired
Alarm/reset	Like 'Alarm', but with short-time reset if the relay is ON and another alarm tries to activate the relay. Time duration of relay OFF is made in 'Off delay' under DEL
Alarm sync. block/R	Like 'Alarm + sync. block', but with short-time reset if the relay is ON and another alarm tries to activate the relay. Time duration of relay OFF is made in 'Off delay' under DEL

Relay overview

The table shows the available relay outputs. The optional relay outputs require additional hardware as option M18.

Relay	Slot	Function	Comments
Relay 1	Slot #1	-	Configurable/Trip NEL 1
Relay 2	Slot #1	-	Configurable/Trip NEL 2
Relay 3	Slot #1	-	PMS alarm
Relay 4	Slot #1	Config. and deload	Open breaker signal activates relay 4
Relay 6	Slot #3	-	Start acknowledge HC 1/Configurable
Relay 7	Slot #3	-	Start acknowledge HC 2/Configurable
Relay 8	Slot #3	Configurable	
Relay 9	Slot #3	Configurable	
Relay 14	Slot #6	Configurable	Option M18/Semi-Auto
Relay 15	Slot #6	Configurable	Option M18/Auto
Relay 16	Slot #6	Configurable	Option M18/Split
Relay 17	Slot #6	Configurable	Option M18/Shaft (Shore)
Relay 18	Slot #7	-	Crank
Relay 19	Slot #7	Alarm	Activates engine stop
Relay 20	Slot #7	-	Start prepare
Relay 26	Slot #1	Configurable	Terminal 20, transistor output
Relay 27	Slot #1	Configurable	Terminal 21, transistor output

Only relays that are configurable can be selected as relays for additional output.

Transducer output (option F1)

The analogue output options each consist of two independent 0(4)…20mA outputs. Each of the two outputs can be chosen to represent any of the following values, or both can represent the same value.

Lamp test

Place the cursor under SETUP and press either arrow up or arrow down. All LEDs except the Power LED will then turn yellow.

Jump menus

A number of menus can only be entered using the jump menu.

Software version (menu number 9000)

Information about the actual software, IP address, gateway and subnet mask downloaded to the unit. Please check this before contacting DEIF regarding service and support matters.

Service menu (menu number 9120)

The service menu can only be entered using the 'JUMP' push-button. This menu is used in service situations. In the alarm selection you can see all the alarm timers and their remaining time, if they are counting. The input and output selections show the present status of the inputs and outputs. E.g. mode inputs, relay outputs and load sharing lines.

Single phase/split phase/three phase (menu number 9130)

The split phase selection is used, if the distribution system is one with 2 phases and neutral. The phases are split 180 degrees. The display shows L1 and L3. The single phase selection is used in a system with one phase (L1) and neutral. The display shows only L1.

Dimmer function of the display backlight and LEDs (menu number 9150)

The adjustment of the illumination intensity of the backlight and the LEDs of each display panel is adjustable by using the 'JUMP' push button. The up or down arrows of the display will make this adjustment and the level of this adjustment will be saved inside the display internal memory after pressing the 'ENTER' push-button.

Trip of Non Essential Load (NEL)

The trip of **N**on **E**ssential **L**oad (NEL) groups is carried out in order to protect the busbar against an imminent blackout situation due to either a high load/current or overload on a generator set or a low busbar frequency.

The trip of NEL groups function is implemented in *each* unit. This means each unit executes the trip of NEL groups according to individual settings. But it is *highly* recommended to programme all units with identical settings in order to obtain a uniform operation.

Each unit is able to trip two NEL groups due to:

- the measured load of the generator set (high load and overload),
- the measured current of the generator set,

and

- the measured frequency at the busbar

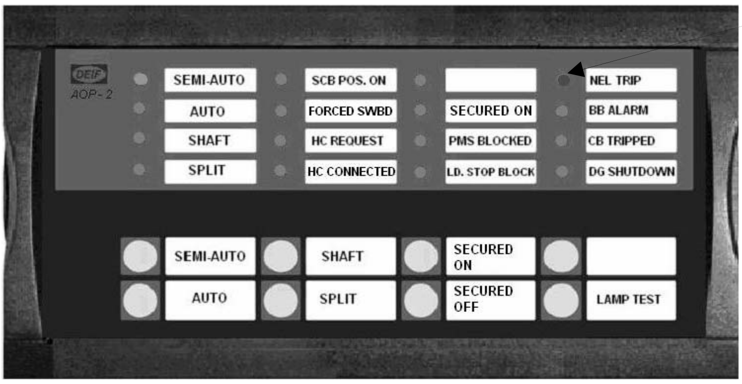
The load groups are tripped as two individual load groups. This means that the trip of load group no. 1 has no direct influence on the trip of load group no. 2. *Only* the measurement of either the busbar frequency or the load/current on the generator set is able to trip the load groups.

Trip of the NEL groups due to the load of a running generator set will reduce the load on the busbar and thus reduce the load percentage on the running generator set. This may prevent a possible blackout at the busbar caused by an overload on the running generator sets. The current trip will be selected in case of inductive loads and unstable power factor (PF < 0.7), where the current is increased.

The overload (push load) trip function of the NEL groups is a fast overload trip.

Trip of the NEL groups due to a low busbar frequency will reduce the real power load at the busbar, and thus reduce the load percentage on all the running generator sets. This may prevent a possible blackout at the busbar.

Additionally the trip of NEL groups will be indicated at the additional operator panel (AOP-2).



The red LED indicates that a non-essential load group has been tripped in the PPM system.

5. Diesel generator

The diesel generator has CAN bus ID no. 1-8. The ID no. can be adjusted in the menu system.

The command unit has as default the CAN bus ID no. 1.

Engine protection

Digital inputs with cable supervision

The diesel generator units have 3 binary inputs **with** wire break supervision available. These inputs are configurable and can be used as:

- Low lubrication oil pressure (with wire break supervision)
- Cooling water temperature high (with wire break supervision)
- Overspeed (with wire break supervision)

The alarm text message and failure class can be changed with the DEIF utility software to the customer demands.

Signal name	Signal type	Location
VDO input 104	Binary input	Terminal 104
VDO input 105	Binary input	Terminal 105
VDO input 106	Binary input	Terminal 106
COMMON (terminals 104-106)		Terminal 107

The wire break resistor is 100 Ω. No 24VDC on terminals, only potential free contacts to be used.

Cable supervision alarms

The cable supervision is separate alarms that can be enabled/disabled.

The wire break resistor has to be 100 Ω. Min.: 0.25w.

Magnetic pick-up RPM

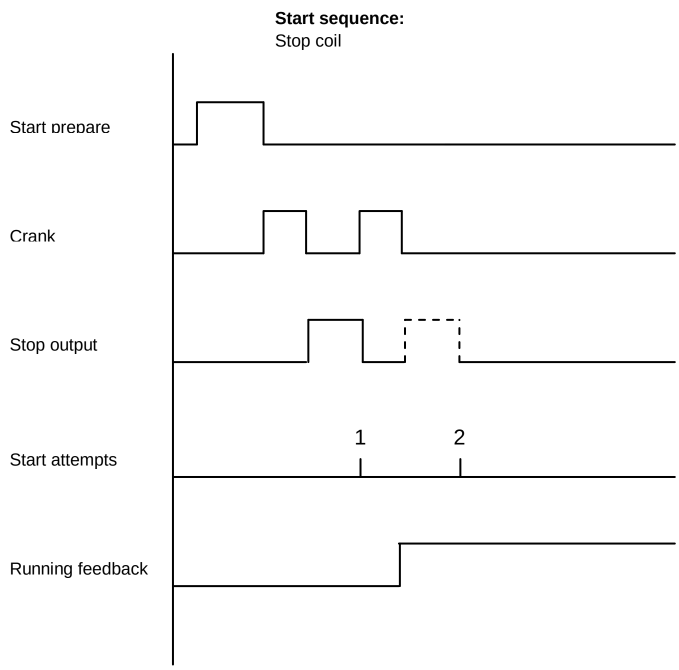
The unit has an input for a magnetic pick-up.

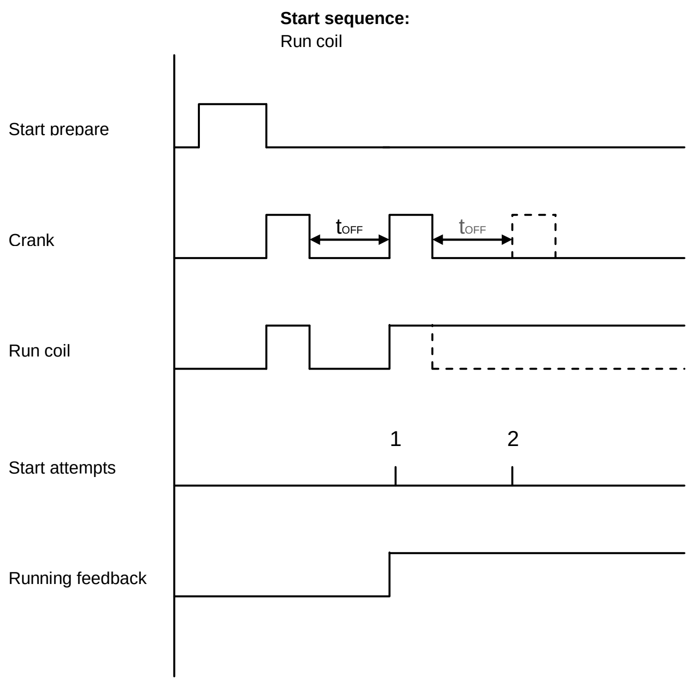
The input range is: 0.5…70V AC
10…10.000Hz

Sequences

START sequence

The drawings below illustrate the start sequences of the gen-set.





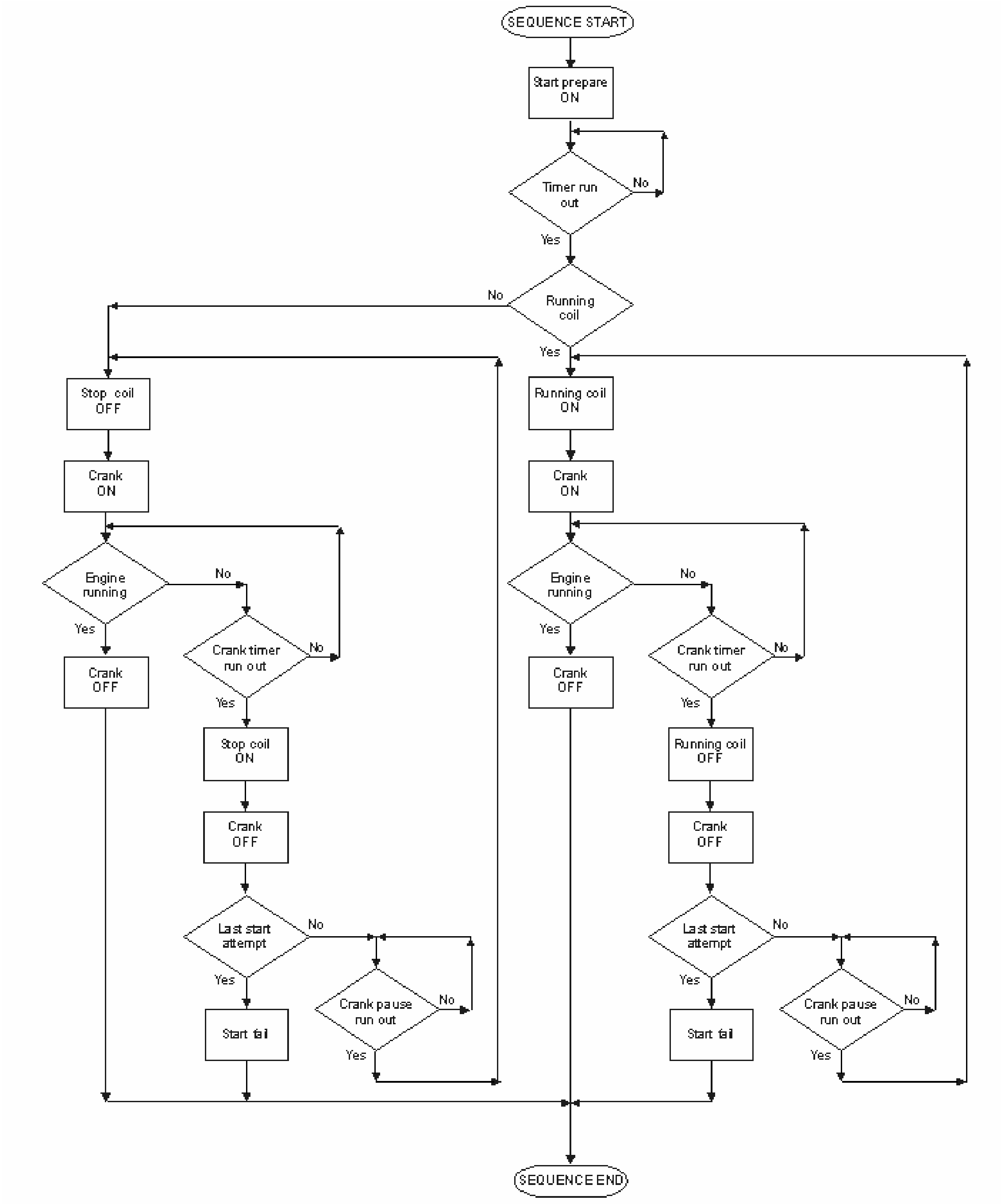
If the tacho input is to be used to remove the starter, it has to be set up in the menu system. If the digital input is to be used as running feedback, then terminal 116 has to be used.

Interruption of start sequence

The start sequence is interrupted in the following situations:

Event	Comment
Stop signal	
Start failure	
Remove starter feedback	Tacho set point
Running feedback	Digital input
Running feedback	Tacho set point
Running feedback	Frequency measurement above 32Hz The frequency measurement requires a voltage measurement of 30% * U_{NOM} The running detection based on the frequency measurement can replace the running feedback based on tacho or digital input or engine communication
Emergency stop	Digital input
Alarm	Alarms with the fail class: (5) Trip + stop, (6) Shutdown, (7) CB short and (8) Sys. alarm
Stop push-button on display	Only in semi-auto
Modbus command	Only in semi-auto
Binary stop input	Only in semi-auto

Flowchart for automatic start sequence



Start prepare

The start prepare timer can be used for start preparation purposes, e.g. prelubrication or preglowing.

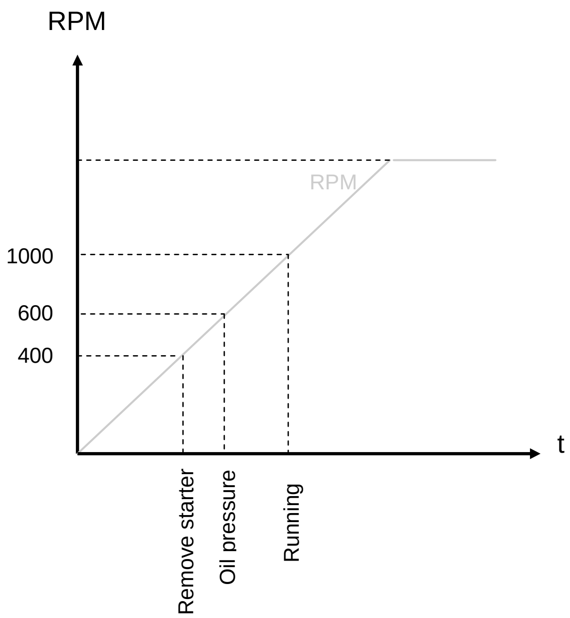
Running detection

The start sequence is deactivated when the running feedback is present.

The running feedback is used to verify that the engine is running and it enables alarms where the inhibit settings are set to RUN.

As the inhibit signal is removed when the engine is detected as running, then alarms with normally short timers have to be taken into consideration.

An example of a fast alarm is the oil pressure alarm. Normally it is configured according to the shutdown fail class. But if the starter motor has to disengage at 400 RPM, and the oil pressure does not reach a level above the shutdown set point before 600 RPM, then, obviously, the gen-set would shut down, if the specific alarm was activated at the preset 400 RPM. In that case, the running feedback must be activated at a higher number of revolutions than 600 RPM.

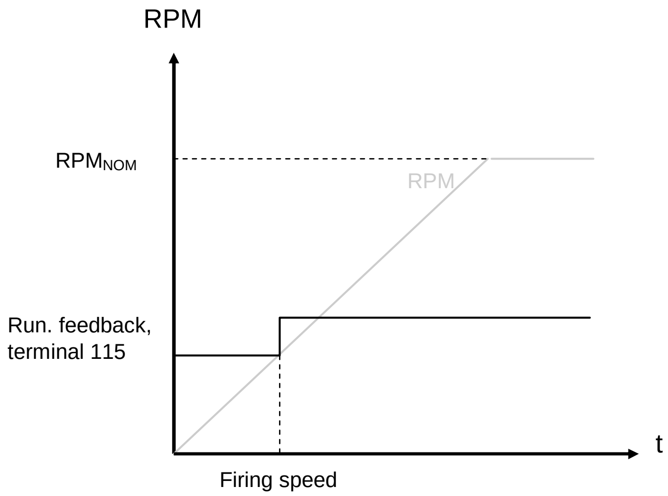


Digital feedbacks

If an external running relay is installed, then the digital control inputs for running detection and remove starter can be used. This input is located at terminal 115.

Running feedback

When the digital running feedback is active, the start relay is deactivated and the starter motor will be disengaged.



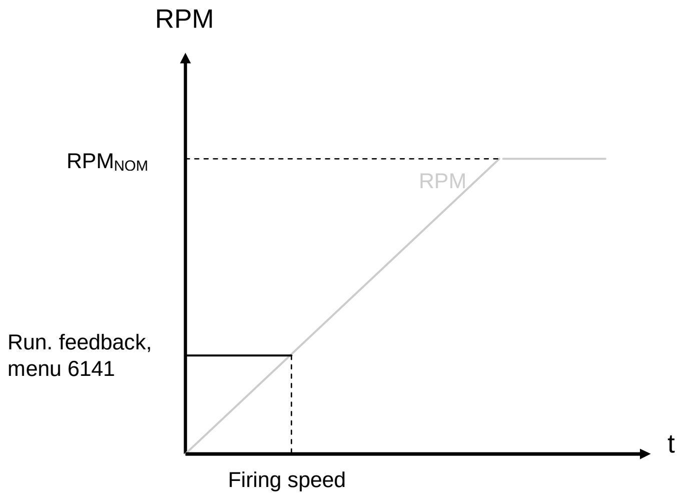
The diagram illustrates how the digital running feedback (terminal 115) is activated, when the engine has reached its firing speed.

Analogue tacho feedback

When a magnetic pick-up is being used, the specific level of revolutions for deactivation of the start relay can be adjusted.

Running feedback

The diagram below shows how the running feedback is detected at the firing speed level. The limit factory setting is 300 RPM.



Tacho configuration

When the number of teeth is set to 0, the running detection based on the tacho input is disabled.

The running feedback is detected by either the digital input, frequency measurement above 32Hz or RPM is measured by magnetic pick-up.

If one of the feedbacks is removed, the unit will still see the gen-set as running, if another type of running detection is present.

Stop sequence

The stop sequence will be activated, when a stop command is given. The stop sequence includes the cooling-down time, if the stop is a normal or controlled stop.

The extended stop timer starts when the running detection goes off. The purpose of this timer is to prevent the starter from engaging an engine still rotating, but without running detection.

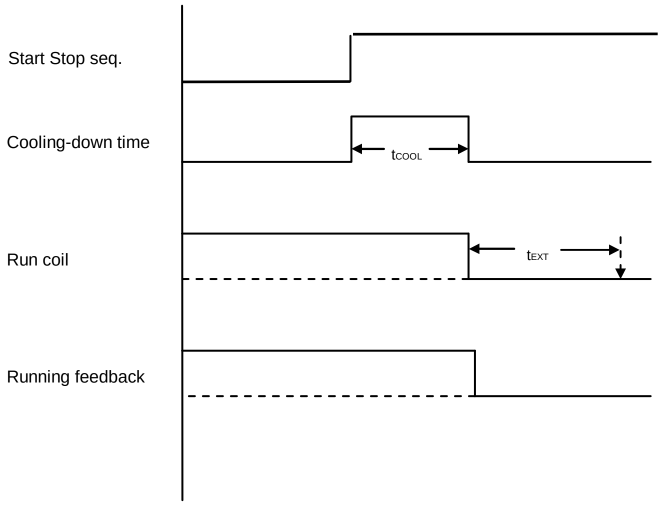
A stop failure alarm will occur, if the running feedback or the generator voltage and frequency are still active after the stop timer has expired.

Description	Cooling-down	Stop	Comment
Auto mode stop	X	X	
Warning and DG prewarning	X	X	
Trip + stop	X	X	
Shutdown		X	
Stop button on display (if pressed 2 times: direct stop)	X	X	Semi-auto
Emergency stop		X	Engine shuts down and GB opens

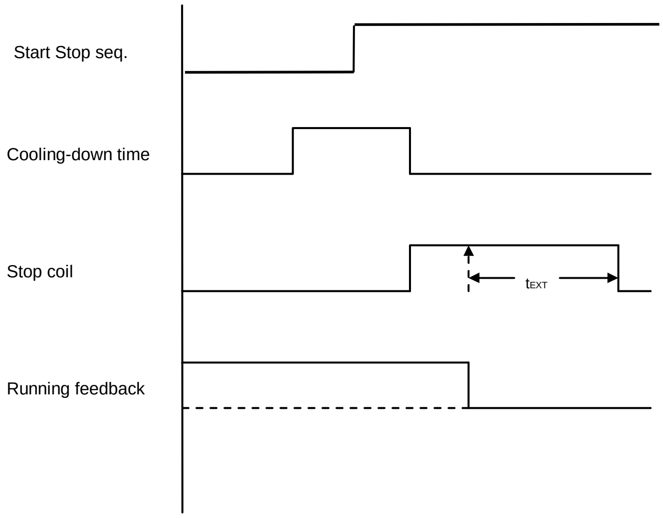
The stop sequence can only be interrupted during the cooling-down period.

The drawings below illustrate the stop sequence:

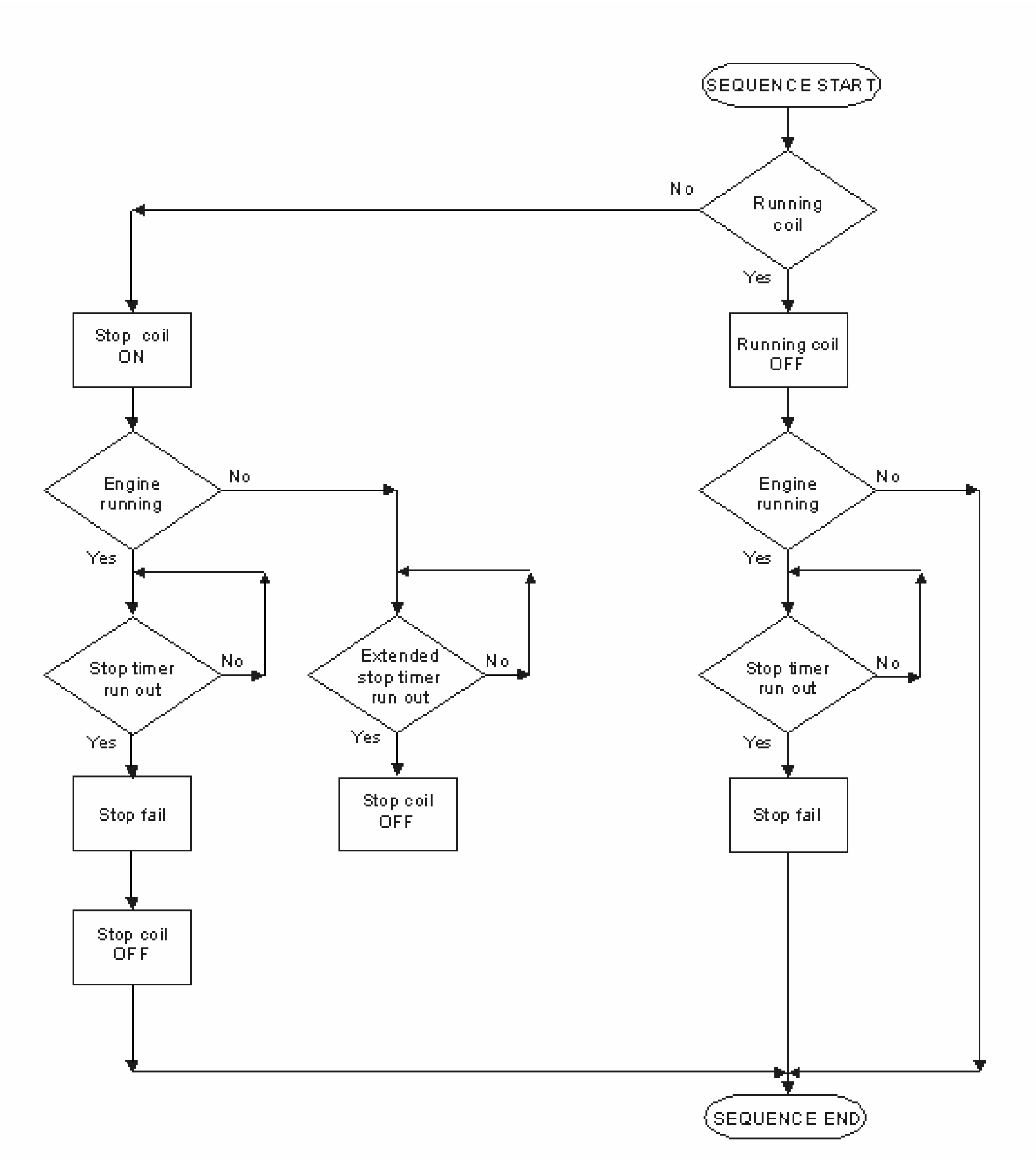
Stop sequence/RUN coil



Stop sequence/STOP coil



Flowchart for automatic stop sequence



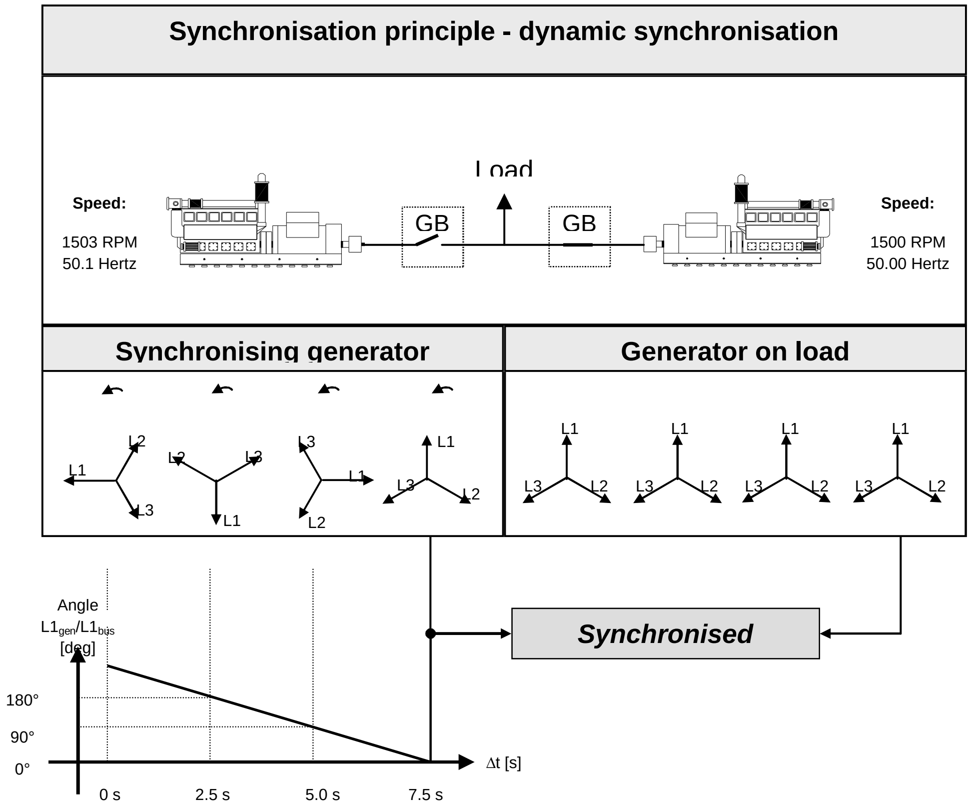
Synchronisation

Two different synchronisation principles are available, namely static and dynamic synchronisation (dynamic is selected by default). This chapter describes the principles of the synchronisation functions and the adjustment of them.

In the following the term 'synchronisation' means *'synchronising and closing of the synchronised breaker'*.

Dynamic synchronisation

The dynamic principle is illustrated below.



In the example above the synchronising gen-set is running at 1503 RPM ~ 50.1Hz. The generator on load is running at 1500 RPM ~ 50.0Hz. This gives the synchronising gen-set a positive slip frequency of 0.1Hz.

The intention of the synchronising is to decrease the phase angle difference between the two rotating systems. These two systems are the three-phase system of the generator and the three-phase system of the busbar. In the illustration above phase L1 of the busbar is always pointing at 12 o'clock, whereas phase L1 of the synchronising gen-set is pointing in different directions due to the slip frequency.

Of course both three-phase systems are rotating, but for illustrative purposes the vectors for the generator on load are not shown to be rotating. This is because we are only interested in the slip frequency for calculating when to release the synchronisation pulse.

When the generator is running with a positive slip frequency of 0.1Hz compared to the busbar, then the two systems will be synchronised every 10 seconds.

$$t_{SYNC} = \frac{1}{50.1 - 50.0} = 10\,\text{sec}$$

In the illustration above the difference in the phase angle between the synchronising set and the busbar gets smaller and will eventually be zero. Then the gen-set is synchronised to the busbar, and the breaker will be closed.

Close signal

The unit always calculates when to close the breaker to get the most accurate synchronisation. This means that the close breaker signal is actually issued before being synchronised (read L1 phases exactly at 12 o'clock).

The breaker close signal will be issued depending on the breaker closing time and the slip frequency (response time of the circuit breaker is 250 ms, and the slip frequency is 0.1Hz):

$$\deg_{CLOSE} = 360 * t_{CB} * f_{SLIP}$$
$$\deg_{CLOSE} = 360 * 0.250 * 0.1$$
$$\deg_{CLOSE} = 9\deg$$

The synchronisation pulse is always issued, so the closing of the breaker will occur at the 12 o'clock position. Here the generator will rotate 9 deg. in 0.250 s.

The length of the synchronisation pulse is the response time + 20 ms.

Load picture after synchronising

When the incoming gen-set has closed its breaker, it will take a portion of the load depending on the actual position of the fuel rack. Illustration 1 below indicates that at a given *positive* slip frequency, the incoming gen-set will *export* power to the load. Illustration 2 below shows that at a given *negative* slip frequency, the incoming gen-set will *receive* power from the original gen-set. This phenomenon is called *reverse power*.

To avoid nuisance trips caused by reverse power, the synchronising settings can be set up with a positive slip frequency.

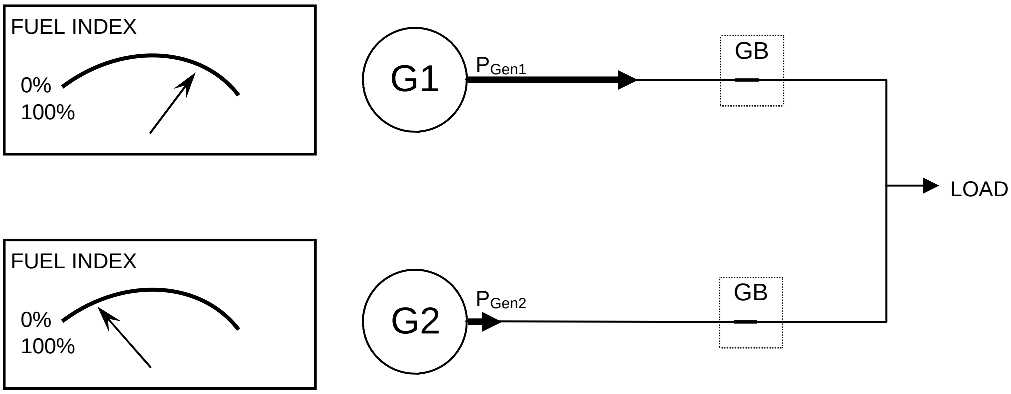


Illustration 1, POSITIVE slip frequency

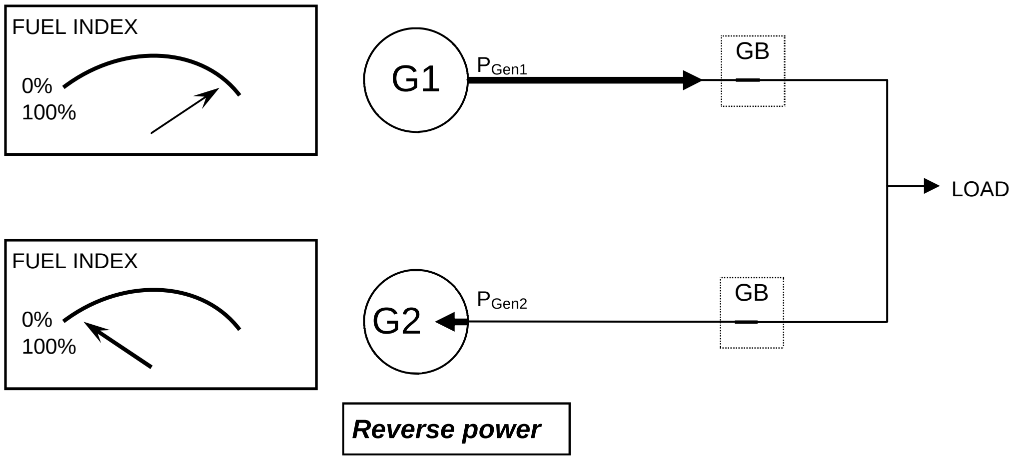


Illustration 2, NEGATIVE slip frequency

It is obvious that this type of synchronisation is able to synchronise relatively fast because of the adjusted minimum and maximum slip frequencies. This actually means that when the unit is aiming to control the frequency towards its set point, then synchronising can still occur as long as the frequency is within the limits of the slip frequency adjustments.

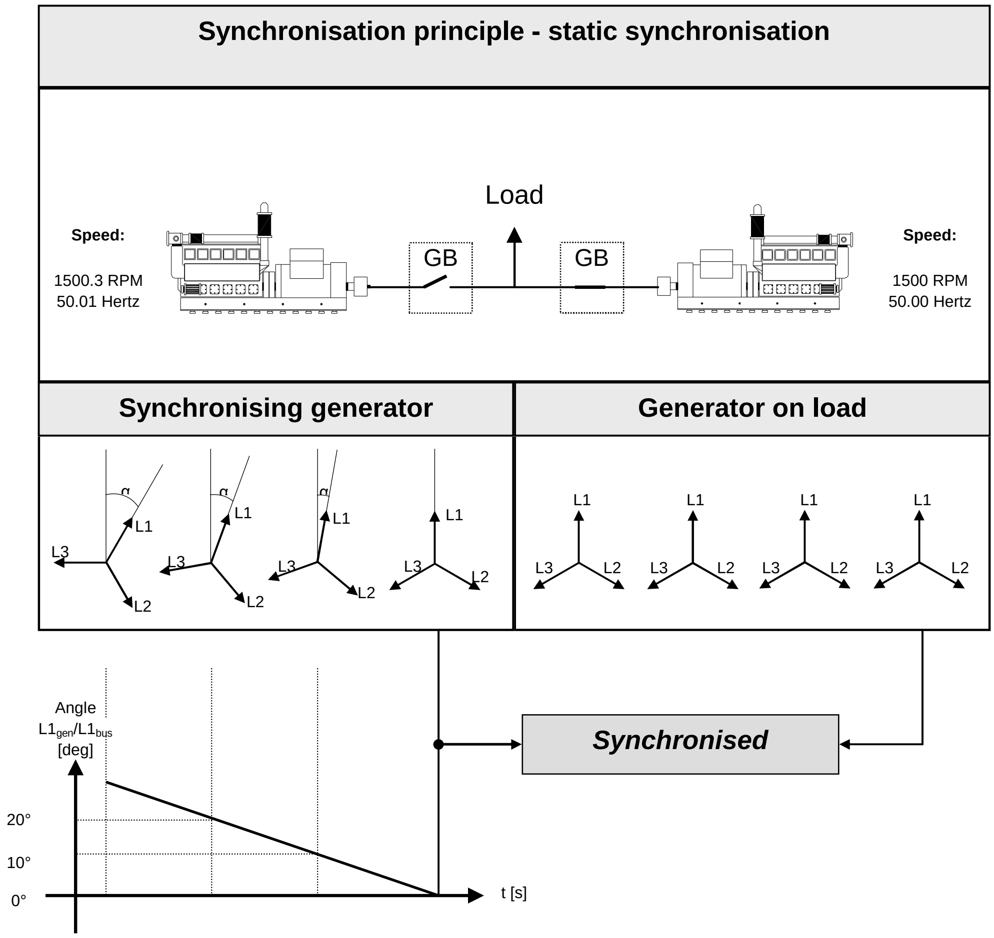
Dynamic synchronisation is recommended where fast synchronisation is required, and where the incoming gen-sets are able to take load just after the breaker has been closed.

Static synchronisation

In static synchronisation the synchronising gen-set is running very close to the same speed as the generator on the busbar. The aim is to let them run at exactly the same speed and with the phase angles between the three-phase system of the generator and the three-phase system of the busbar matching exactly.

It is not recommended to use the static synchronisation principle when relay regulation outputs are used. This is due to the slower nature of the regulation with relay outputs.

The static principle is illustrated below.



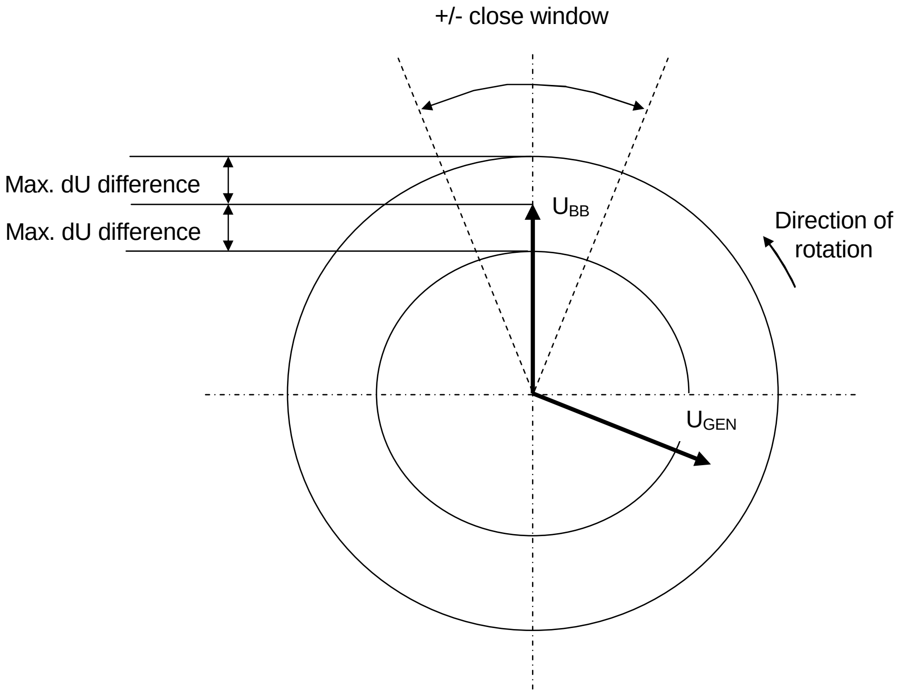
Phase controller

When the static synchronisation is used and the synchronising is activated, the frequency controller will bring the gen-set frequency towards the busbar frequency. When the gen-set frequency is within 50mHz of the busbar frequency, then the phase controller takes over. This controller uses the angle difference between the generator system and the busbar system as the controlling parameter. This is illustrated in the example above where the phase controller brings the phase angle from 30 deg. to 0 deg.

Close signal

The close signal will be issued when phase L1 of the synchronising generator is close to the 12 o'clock position compared to the busbar which is also in 12 o'clock position. It is not relevant to use the response time of the circuit breaker when using static synchronisation, because the slip frequency is either very small or non-existing.

To be able to get a faster synchronisation, a 'close window' can be adjusted. The close signal can be issued when the phase angle U_{GENL1}-U_{BBL1} is within the adjusted set point. The range is +/-0.1-20.0 deg. This is illustrated in the drawing below.



The synchronisation pulse is sent dependent on the preset settings, depending on whether it is the GB or the MB which is to be synchronised.

Load picture after synchronisation

The synchronised gen-set will not be exposed to an immediate load after the breaker closure, if the maximum df setting is adjusted to a low value. Since the fuel rack position almost exactly equals what is required to run at the busbar frequency, no load jump will occur.

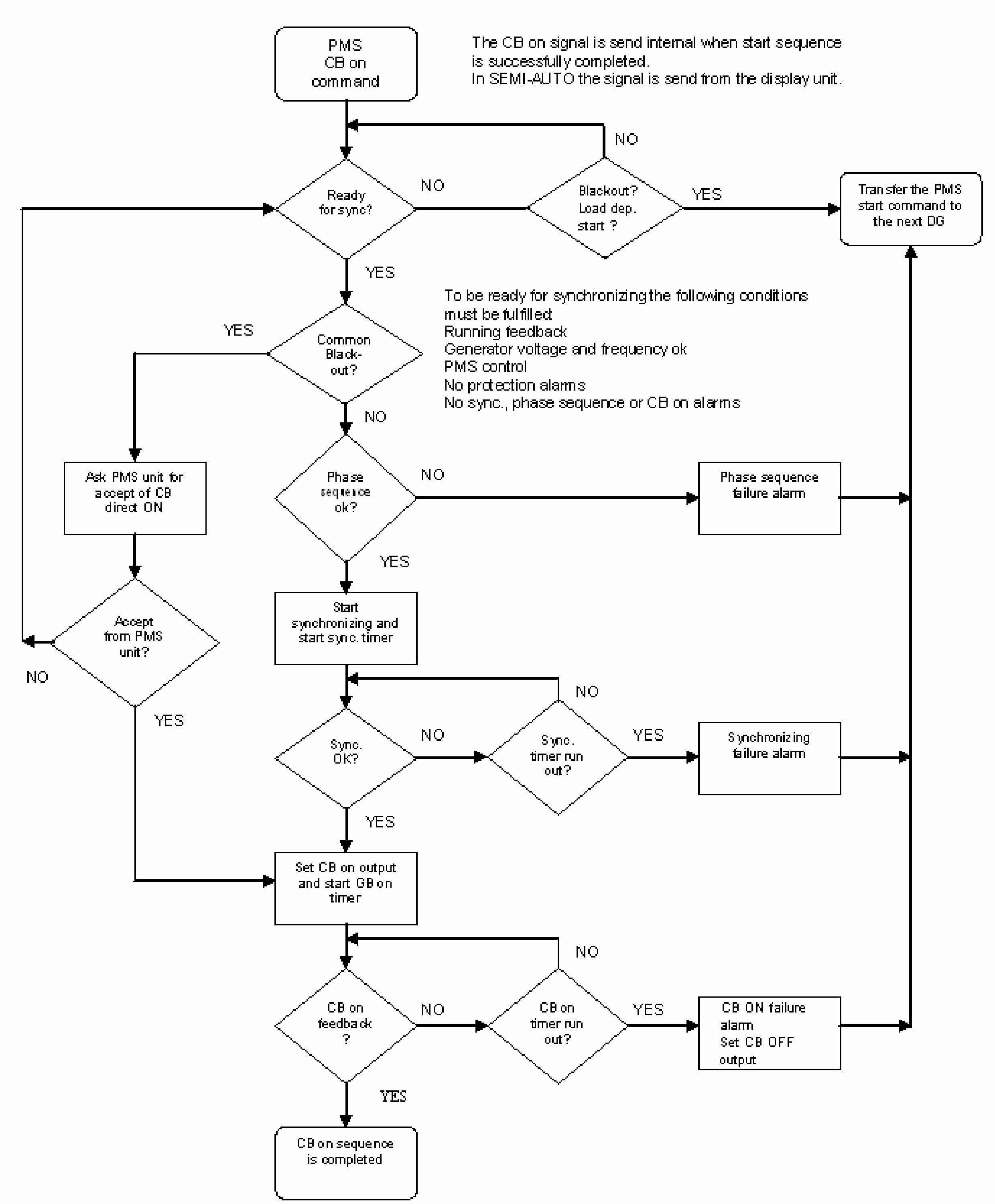
If the maximum df setting is adjusted to a high value, then the observations in the section about 'dynamic synchronisation' must be observed.

After the synchronising, the unit will change the controller set point according to the requirements of the selected gen-set mode.

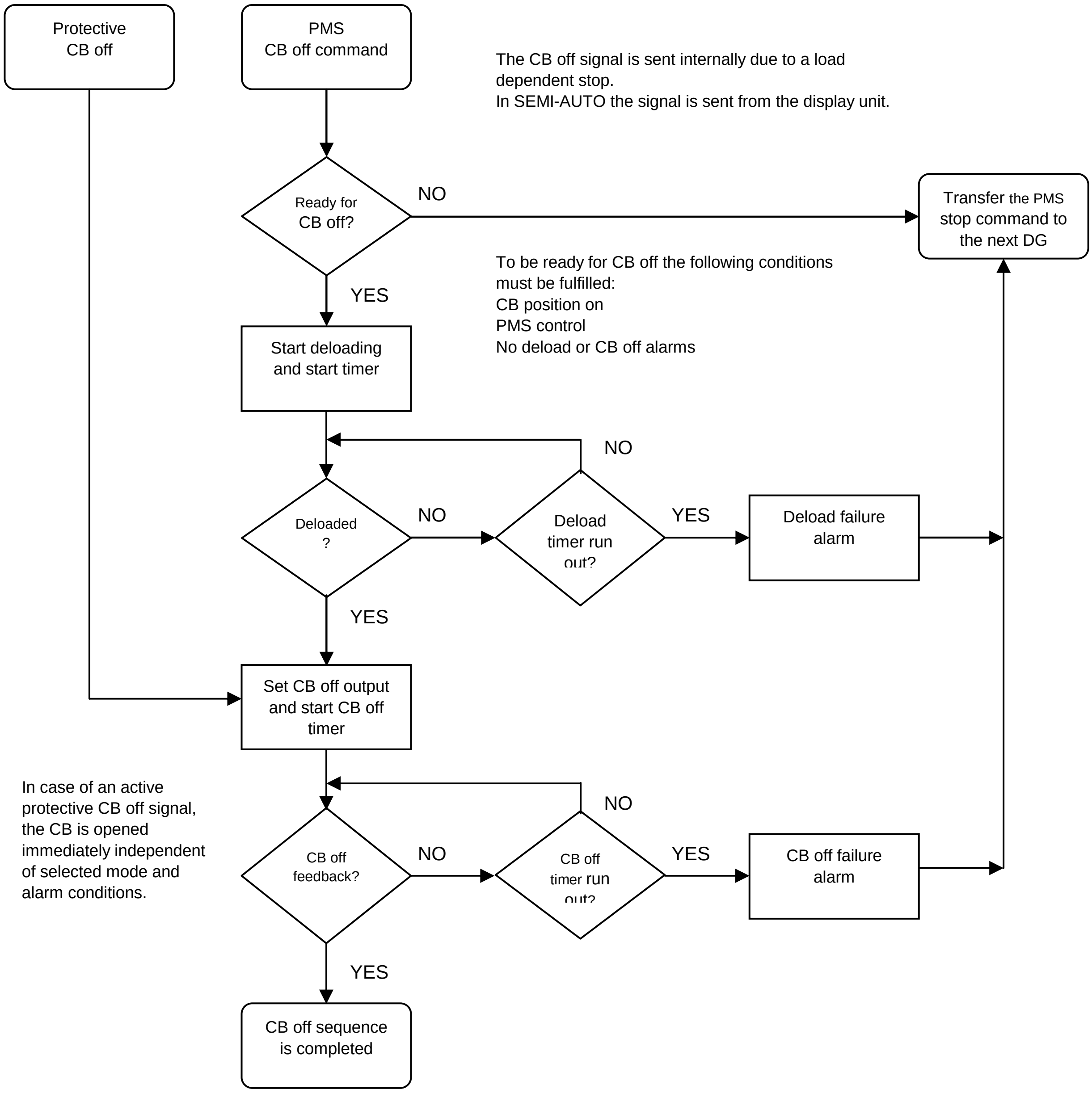
Static synchronisation is recommended, where a slip frequency is not accepted, for instance if several gen-sets synchronise to a busbar with no load groups connected.

The static synchronisation uses a separate phase regulator which is only active during synchronisation.

CB ON sequence



CB OFF sequence



Common settings for synchronisation

Blackout synchronisation

The settings in the blackout synchronisation open a window where the generator frequency and voltage will be accepted as being valid. When the frequency and the voltages are within the window, then the generator will indicate to the PMS system that it is ready to close. The voltage and frequency have to be within the window for a period of time.

Synchronisation failure

The connection breaker has not been able to close within the specified time delay for synchronisation.

Phase sequence failure

A negative sequential order of phases has been detected at the generator with regards to the busbar.

CB open failure

The CB open failure will occur, if the unit has transmitted a CB open signal and the CB feedback has not changed position from ON to OFF within 2 s.

CB close failure

The CB close failure will occur, if the unit has transmitted a CB close signal and the CB feedback has not changed position from OFF to ON within 2 s.

CB position failure

If the CB feedbacks for ON and OFF both are missing for more than 2 s.

Regulation

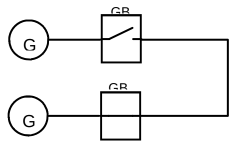
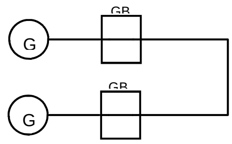
The unit controller is a PI controller. It consists of a proportional regulator and an integral regulator. The PI controller is able to eliminate the regulation deviation and can easily be tuned in.

Controllers

There are two controllers for the governor control and, if option D1 is selected, also two controllers for the AVR control.

Controller	GOV	AVR	Comment
Frequency	X		Controls the frequency
Power	X		Controls the power
Voltage (option D1)		(X)	Controls the voltage
VAr (option D1)		(X)	Controls the VAr

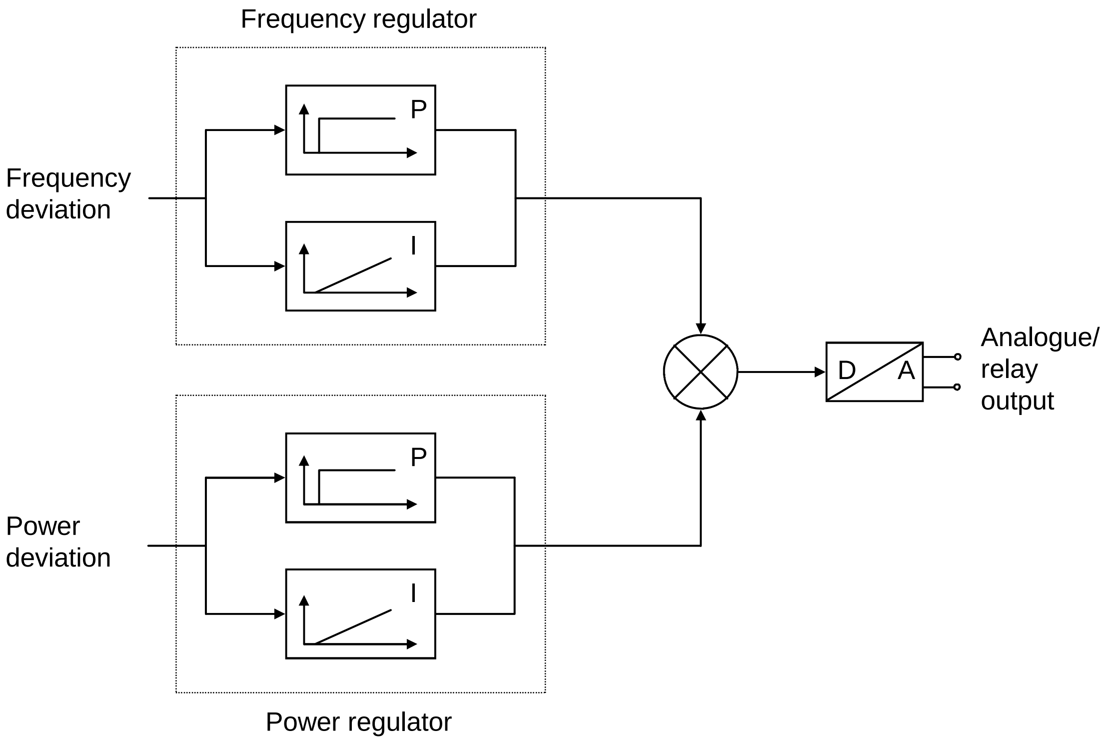
The table below indicates when each of the controllers is active. This means that the controllers can be tuned in when the shown running situations are present.

Governor		**AVR (option dependent)**		**Schematic**
Frequency	**Power**	**Voltage**	**VAr**	
X		(X)		
X	X	(X)	(X)	

The frequency (and voltage) controller is activated when the gen-set is running in island operation or stand-alone. The power (and VAr) controller is activated when the gen-set is running in parallel.

Principle drawing

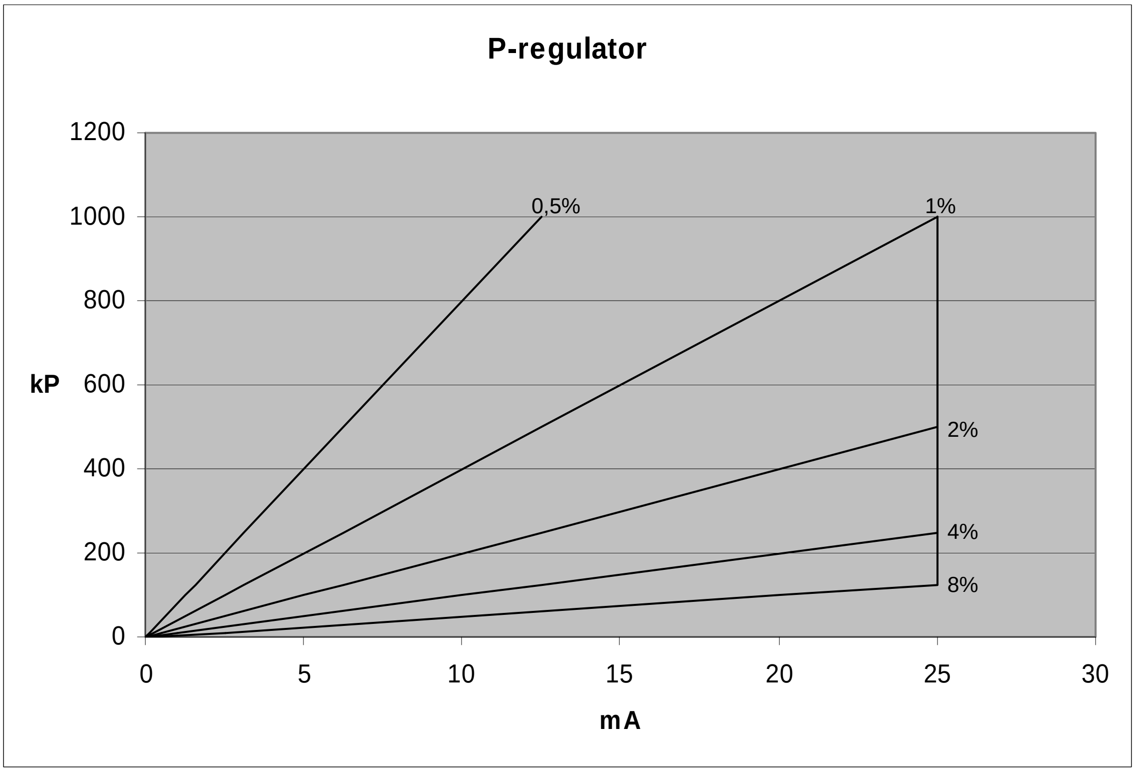
The drawing below shows one PI regulator for the frequency control and one PI regulator for the power control. The output from each regulator is added and converted to the output stage which, in this case, is the analogue output. PWM or relay outputs can also be used.



Proportional regulator

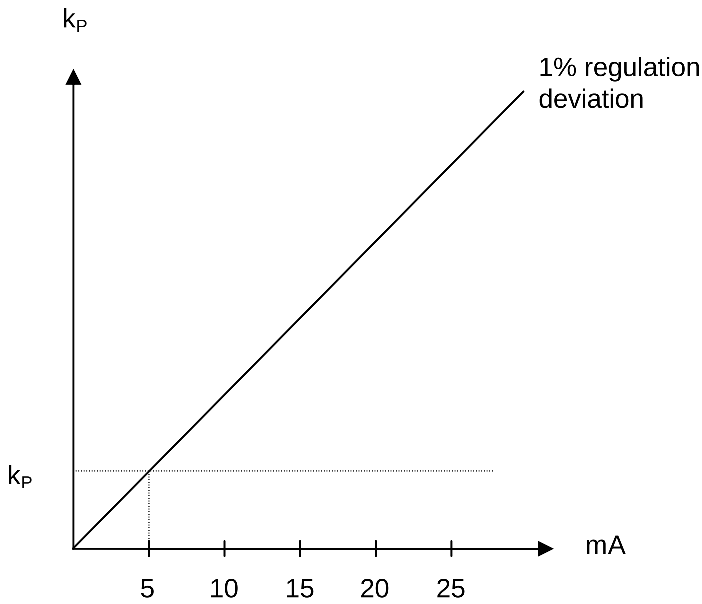
When the regulation deviation occurs, the proportional part will cause an immediate change of the output. The size of the change depends on the proportional action coefficient, KP.

The diagram shows how the output of the P regulator depends on the KP setting. The change of the output at a given KP setting will be doubled, if the regulation deviation doubles.



Speed range

Because of the characteristic above it is recommended to use the full range of the output to avoid an unstable regulation. If the output range used is too small, a small regulation deviation will cause a rather big output change. This is shown in the drawing below.

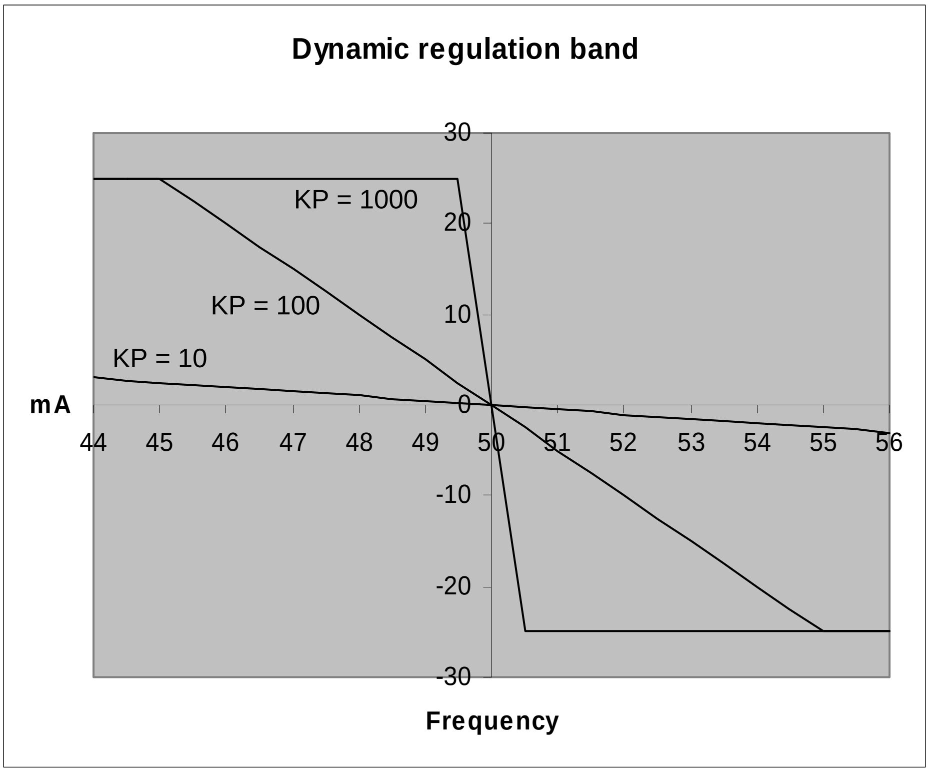


A 1% regulation deviation occurs. With the KP setting adjusted, the deviation causes the output to change 5mA. The table shows that the output of the PPM changes relatively much, if the maximum speed range is low.

Max. speed range	**Output change**		**Output change in % of max. speed range**
10mA	5mA	5/10*100%	50
20mA	5mA	5/20*100%	25

Dynamic regulation area

The drawing below shows the dynamic regulation area at given values of KP. The dynamic area gets smaller, if the KP is adjusted to a higher value.

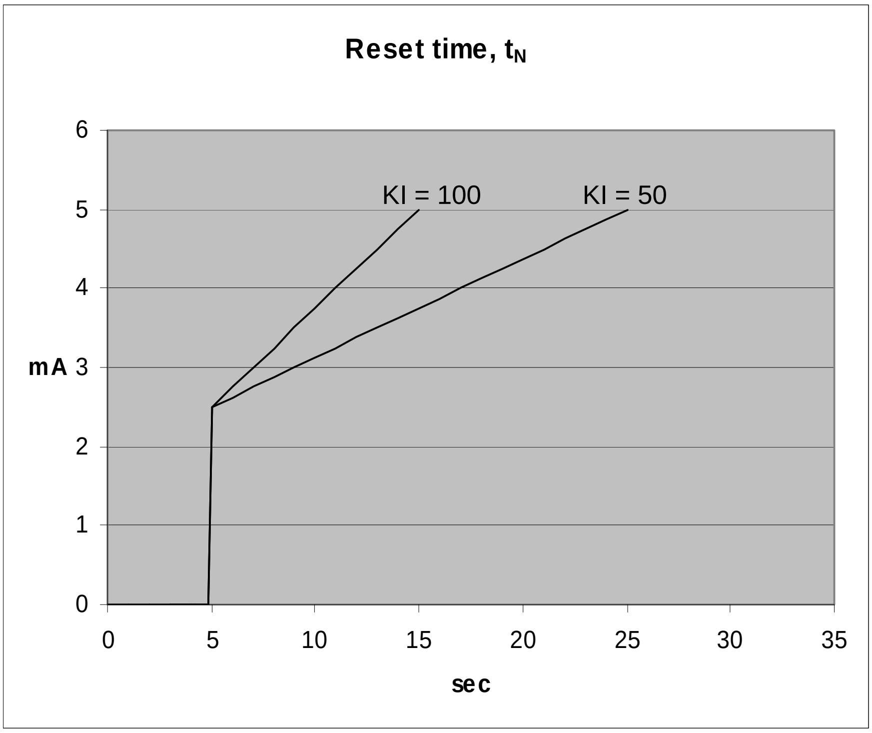


Integral regulator

To illustrate the integral action coefficient, the KI reset time can be used. The reset time is defined as the time the integral regulator uses to replicate the momentary change of the output caused by the proportional regulator.

In the drawing below the proportional regulator causes an immediate change of 2.5mA. The reset time is then measured when the output reaches 2 x 2.5mA = 5mA.

The drawing shows that when the KI setting is changed to half the value, then the reset time is doubled. The reset time is 10 seconds with a KI setting of 100. With the KI setting adjusted to 50 the reset time will be 20 seconds. The KP setting is 100 in this example.



The reset time of the unit can be calculated at all values of KP and KI with the formula:

$$t_N = k_P * 10 / k_I$$

The table shows theoretical reset times in seconds:

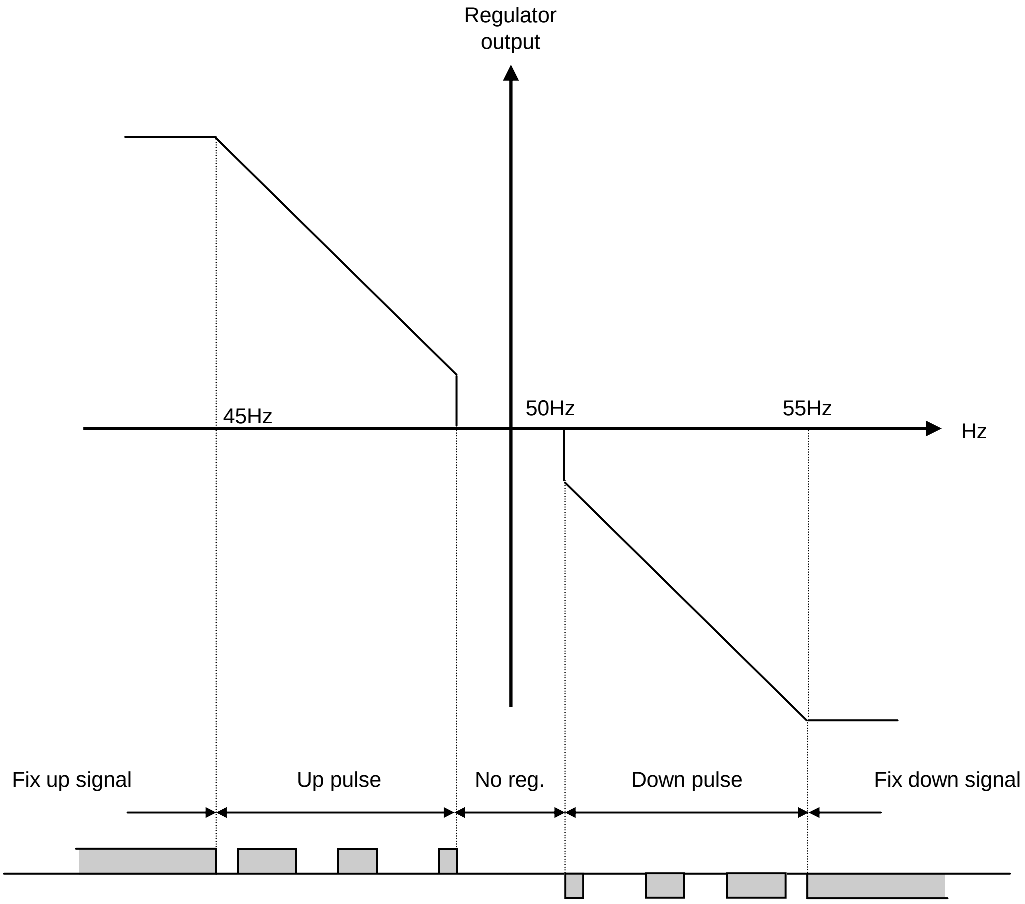
k_I / k_P	1	10	100	1000
1	10	1	0.1	0.01
10	100	10	1	0.1
100	1000	100	10	1
1000	10000	1000	100	10

The integrating function of the I regulator is increased, if the integral action coefficient, KI, is increased. This means that the reset time gets smaller and a faster I regulation is achieved. If the KI is adjusted to 0 (reset time endless), the I regulator is switched off.

The integral action coefficient, KI, must not be too high. This will make the regulation hunt similar to a too high proportional action factor, KP.

Relay control

When the relay outputs are used for control purposes, the regulation is performed like this:



The regulation with relays can be split up into five steps.

#	Range	Description	Comment
1	Static range	Fix up signal	The regulation is active, but the increase relay will be constantly activated because of the size of the regulation deviation.
2	Dynamic range	Up pulse	The regulation is active, and the increase relay will be pulsing in order to eliminate the regulation deviation.
3	Dead band area	No reg.	In this particular range no regulation takes place. The regulation accepts a predefined dead band area in order to increase the lifetime of the relays.
4	Dynamic range	Down pulse	The regulation is active, and the decrease relay will be pulsing in order to eliminate the regulation deviation.
5	Static range	Fix down signal	The regulation is active, but the decrease relay will be constantly activated because of the size of the regulation deviation.

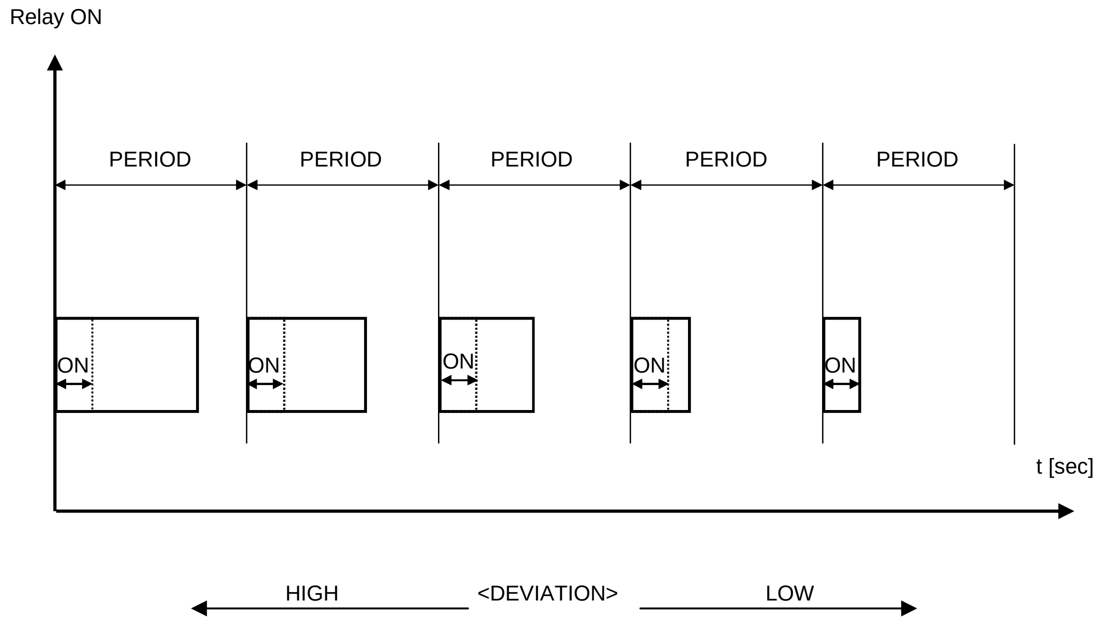
As the illustration indicates, the relays will be fixed on if the regulation deviation is big, and they will be pulsing if it is closer to the set point. In the dynamic range the pulses get shorter and shorter when the regulation deviation gets smaller. Just before the dead band area the pulse is as short as it can get. This is the adjusted time 'GOV ON time'/('AVR ON time'). The longest pulse will appear at the end of the dynamic range (45Hz in the example above).

Relay adjustments

The time settings for the regulation relays can be adjusted in the control setup. It is possible to adjust the 'period' time and the 'ON time'. They are shown in the drawing below.

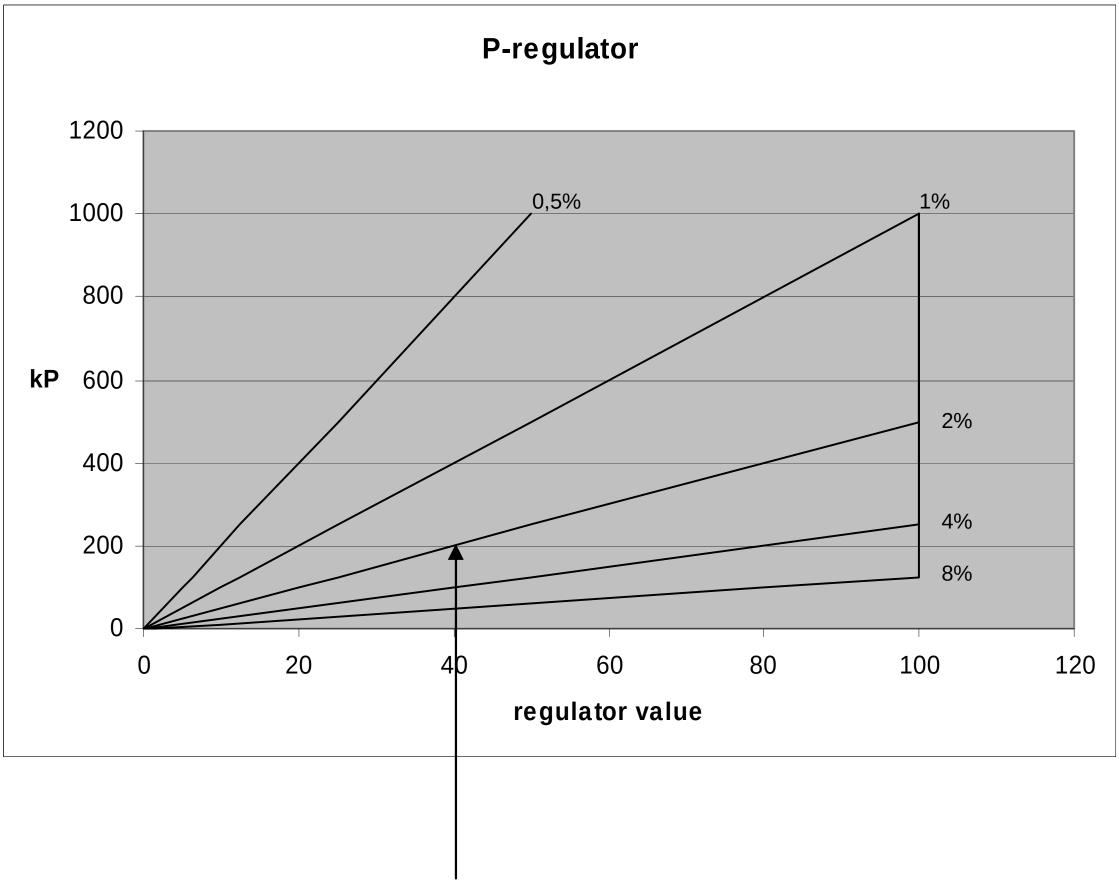
Adjustment	Description	Comment
Period time	Maximum relay time	The time between the beginnings of two subsequent relay pulses.
ON time	Minimum relay time	The minimum length of the relay pulse. The relays will never be activated for a shorter time than the ON time.

As it is indicated in the drawing below, the length of the relay pulse will depend on the actual regulation deviation. If the deviation is big, then the pulses will be long (or a continued signal). If the deviation is small, then the pulses will be short.



Signal length

The signal length is calculated compared to the adjusted period time. In the drawing below the effect of the proportional regulator is indicated.



In this example we have a 2 percent regulation deviation and an adjusted value of the KP = 200. The calculated regulator value of the unit is 40%. Now the pulse length can be calculated with a period time = 2500 ms:

$$e_{DEVIATION} / 100 * t_{PERIOD}$$

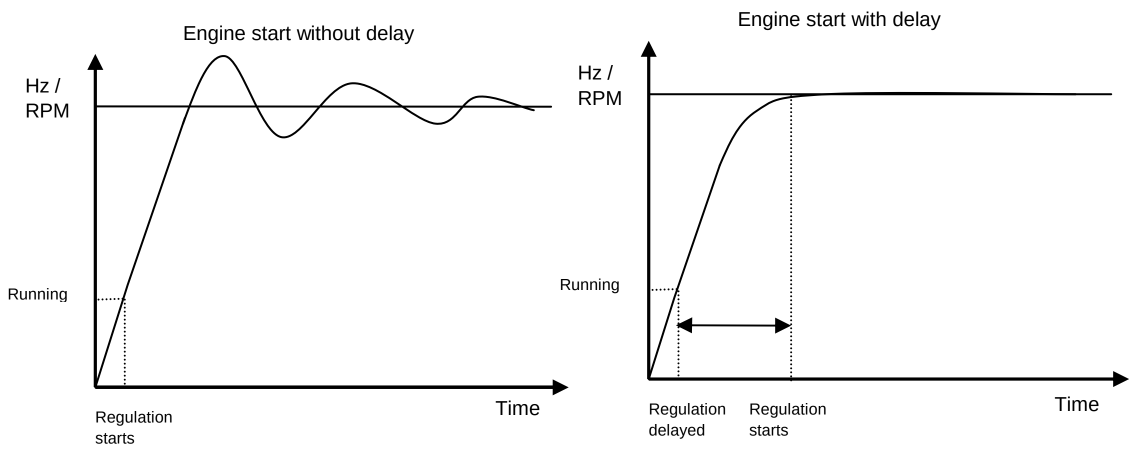
$$40 / 100 * 2500 = 1000 ms$$

The length of the period time will never be shorter than the adjusted ON time. The P regulator causes the relay output to activate. The I regulator has the same effect on the relay output as described on page 47 concerning the reset time t_N.

Delay regulation

The frequency regulator will normally start regulating as soon as the unit receives a running feedback. During the start the running feedback will most likely be set around 30Hz or before. The regulator will then increase in order to control the generator up to 50/60Hz. This increase will then cause the generator to overshoot the nominal frequency and prolong the regulation time before the generator will run at its nominal speed. In order to avoid this, it is possible to delay the regulation for a few seconds, so the generator will have reached its nominal speed before the regulation starts.

If the regulation delay is not wanted, set the time to 0 (factory setting).



The enable function relates to the relay outputs only. Setting it OFF will not disable the delay function, only the relay outputs. The relay outputs can be used to send a 'Regulation ON' signal to another system, using relay output(s) set to limit function.

An active timer for the delay regulation is indicated by a yellow "Regulation" LED on the display unit.

Generator load control

The *PPU Power Management system* can control speed governors/AVRs using relay or analogue outputs.

Control of speed governor

If the prime mover is provided with a mechanical speed governor, this must be equipped with a pilot motor for manual/automatic remote control of the prime mover. The two relay outputs from the unit may then in conjunction with a supply voltage for the pilot motor control the mechanical speed governor.

If the prime mover is provided with an electronic speed governor, the analogue governor control output may be chosen. Manual control is still possible via binary inputs on the multi-line 2, or an 'electronic potentiometer' (EPN-110DN or EP-Q96) is applied to manual/automatic remote control of the diesel engine. The 2 relay outputs from the multi-line 2 can then control the electronic speed governor through the EPN-110DN or EP-Q96.

Re EPN-110DN: Ref.: Data sheet no. 4921240126.
Re EP-Q96: Ref.: Data sheet no. 4921240020.

Adjustment of speed governors

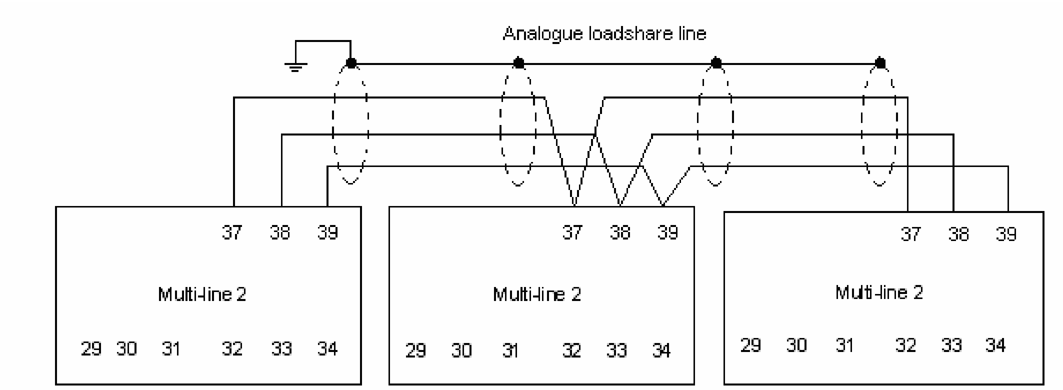
Mechanical/electronic speed governors must ALWAYS be adjusted to an INTERNAL speed droop, irrespective of the control mode being isochronous mode, to ensure stability at manual as well as automatic control! A speed droop of 4% is the rule-of-thumb setting.

Isochronous mode

The term 'Isochronous' refers to load independent frequency control, i.e. the frequency is kept constant at 50/60Hz at 0...100% load.

The speed droop setting on the governor is still necessary to make sure the unit is able to do its job - load sharing and frequency control.

The load sharing between the units will be done via the analogue load share line.



The *PPU Power Management* can carry out the following standard running modes:

- Fixed frequency control (stand-alone single generator)
- Fixed power control (base load)
- Active load sharing control

If the voltage/var (reactive power)/power factor control option is chosen, the following available running modes are added:

- Fixed voltage control (stand-alone single generator)
- Fixed var control (base var)
- Fixed power factor control
- Reactive load sharing control

Symmetrical load sharing

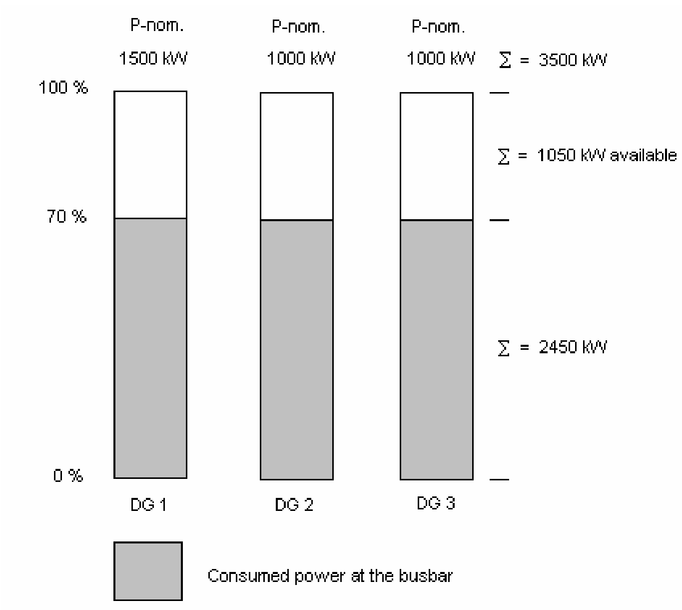
The *PPU Power Management* handles symmetrical load sharing control in each unit, which fulfils the following conditions:

- PMS control is selected
- Do not carry out base load

Symmetrical load sharing is always carried out as default by the system.

During symmetrical load sharing, all running diesel generators are producing the same percentage of their nominal power as the frequency-controlling unit.

Each diesel generator unit calculates the sum of power and the number of diesel generators, which fulfil the conditions for running symmetrical load sharing. The load control reference for each diesel generator unit is the sum of power divided with the number of diesel generator units, scaled in percent.



Symmetrical load share carried out by 3 generator sets.

If the running generator sets have the *same nominal power*, they are loaded equally with real power (kW).

If, however, the generators have *different nominal power*, they are loaded proportionally according to their size. This loads all generators with the same percentage of their nominal power.

Stop of non-connected diesel generators

A generator set may be left running idle e.g. due to generator frequency or voltage failure during the automatic start sequence. Likewise, a generator started during SEMI-AUTO mode will be left running idle when AUTO mode is selected.

A running generator like described above will be stopped after a time by this function (to preserve fuel, minimize attrition etc.) called 'stop of non connected DG'.

Any generator set which has an active generator protection function is not stopped by the function for stop of non-connected generator sets ('Trip of GB alarm sequence').

When the internal timer runs out (60.0 s), the automatic stop sequence with cooling down is initiated as under a normal stop situation. If the operator wants to have a DG running idle, it has to be set in SWBD control.

6. Shaft generator

The shaft generator has CAN bus ID no. 10. This ID no. can be adjusted in the menu system.

The shaft generator unit has ID no. 10.

Protection

Digital inputs with cable supervision

The shaft generator unit has 3 binary inputs **with** wire break supervision available. These inputs are configurable and can for example be used as:

- ME FAILURE (with wire break supervision)

The alarm text message and failure class can be changed with the DEIF utility software to fit customer demands.

SIGNAL NAME	SIGNAL TYPE	LOCATION
• VDO input 104	Binary input	Terminal 104
• VDO input 105	Binary input	Terminal 105
• VDO input 106	Binary input	Terminal 106
• COMMON (terminal 104-106)		Terminal 107

The wire break resistor is 100 Ω. No 24V DC on terminals, only potential free contacts to be used.

Cable supervision alarms

The cable supervision is separate alarms that can be enabled/disabled.

The wire break resistor has to be 100 Ω. Min.: 0.25W.

As the PMS system is not able to stop the main engine due to an alarm on the shaft generator, all fail classes that open the CB automatically change the mode to AUTO.

Running detection

Running detection for the shaft generator is only used for inhibit or not inhibit of alarms. The shaft generator unit has the same possibilities for running detection as a diesel generator unit. But it has no start/stop logic or regulation.

Digital feedbacks

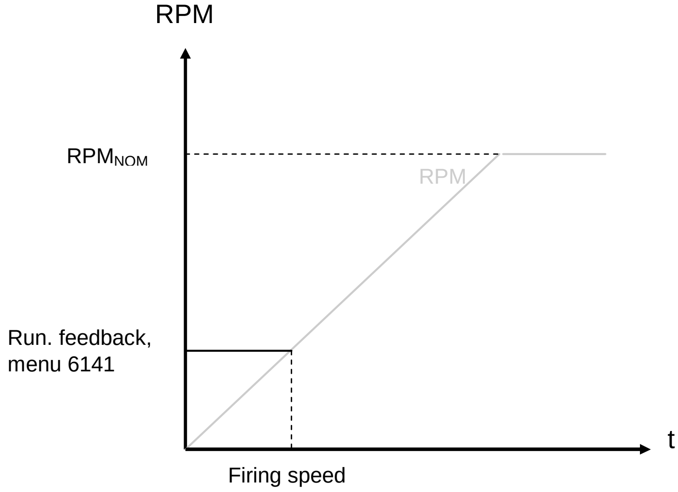
If an external running relay is installed, then the digital control input for running detection can be used. This input is located at terminal 115.

Analogue tachometer feedback

When a magnetic pick-up is being used, the specific level of revolutions for deactivation of the running detection can be adjusted.

Running feedback

The diagram below shows how the running feedback is detected at the firing speed level. The limit factory setting is 300 RPM



When the number of teeth is set to 0, the running detection based on the tacho input is disabled.

The running feedback is detected by either the digital input, frequency measurement above 32Hz or RPM is measured by magnetic pick-up.

If one of the feedbacks is removed, the unit will still see the gen-set as running if another type of running detection is present.

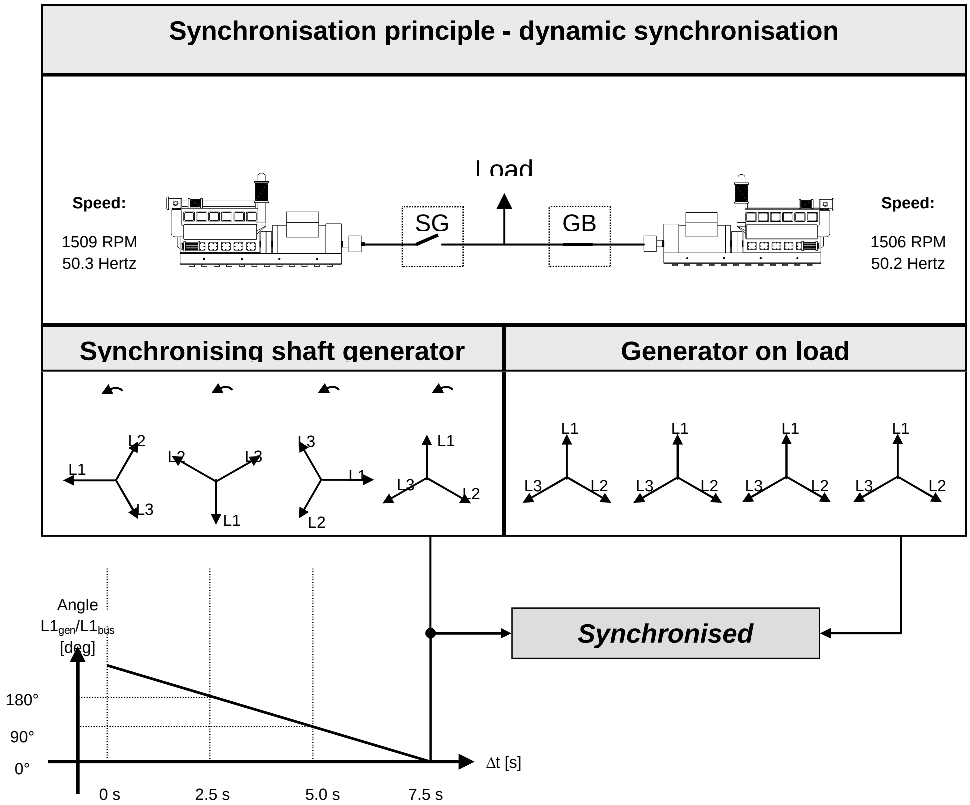
Synchronisation

For the shaft generator only dynamic synchronisation is available. When the shaft generator is being synchronised the actual frequency control is performed by the generators, while the shaft generator unit is only monitoring the difference in order to close the circuit breaker at the right time.

In the following the term 'synchronisation' means *'synchronising and closing of the synchronised breaker'*.

Dynamic synchronisation

In dynamic synchronisation the synchronising gen-set is running at a different speed than the shaft generator. This speed difference is called *slip frequency*. Typically, the synchronising gen-set is running with a negative slip frequency towards the shaft generator. This means that shaft generator under synchronisation is running with a higher speed than the generators. The objective is to avoid a reverse power trip after the synchronisation, as the shaft generator with the higher speed will take load after the circuit breaker has closed.



In the example above the shaft generator is running at 1509 RPM ~ 50.3Hz. The generator on load is running at 1506 RPM ~ 50.2Hz. This gives the shaft generator a positive slip frequency of 0.1Hz. The intention of the synchronising is to decrease the phase angle difference between the two rotating systems. These two systems are the three-phase system of the generator and the three-phase system of the busbar. On the illustration above, phase L1 of the busbar is always pointing at 12 o'clock, whereas phase L1 of the synchronising gen-set is pointing in different directions due to the slip frequency.

Of course both three-phase systems are rotating, but for illustrative purposes the vectors for the generator on load are not shown to be rotating. This is because we are only interested in the slip frequency for calculating when to release the synchronisation pulse.

When the generator is running with a negative slip frequency of 0.1Hz compared to the shaft generator, then the two systems will be synchronised every 10 seconds.

$$t_{SYNC} = \frac{1}{50.1 - 50.0} = 10\,\text{sec}$$

In the illustration above the difference in the phase angle between the synchronising shaft generator and the generator gets smaller and will eventually be zero. Then the shaft generator is synchronised to the generator and the breaker will be closed.

Close signal

The unit always calculates when to close the breaker to get the most accurate synchronisation. This means that the close breaker signal is actually issued before being synchronised (read L1 phases exactly at 12 o'clock).

The breaker close signal will be issued depending on the breaker closing time and the slip frequency (response time of the circuit breaker is 250 ms, and the slip frequency is 0.1Hz):

$$\deg_{CLOSE} = 360 * t_{CB} * f_{SLIP}$$
$$\deg_{CLOSE} = 360 * 0.250 * 0.1$$
$$\deg_{CLOSE} = 9\deg$$

The synchronisation pulse is always issued, so the closing of the breaker will occur at the 12 o'clock position. Here the generator will rotate 9 deg. in 0.250 s.

The length of the synchronisation pulse is the response time + 20 ms.

Load picture after synchronising

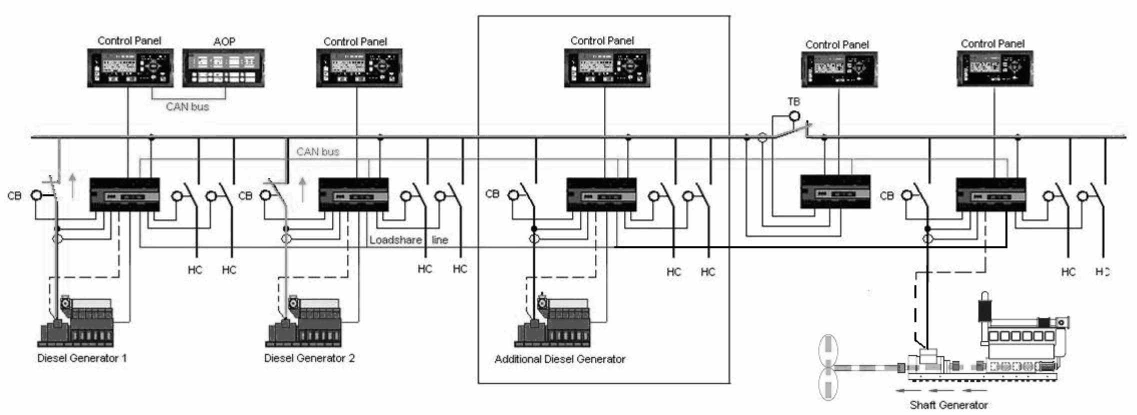
When the shaft generator has closed its breaker, it will take a portion of the load depending on the slip frequency and the difference between the size of the shaft generator corresponding to the size of the connected generators.

This type of synchronisation is able to synchronise relatively fast because of the adjusted minimum and maximum slip frequencies. This actually means that when the unit is aiming to control the frequency towards its set point, then synchronising can still occur as long as the frequency is within the limits of the slip frequency adjustments.

PTH operation

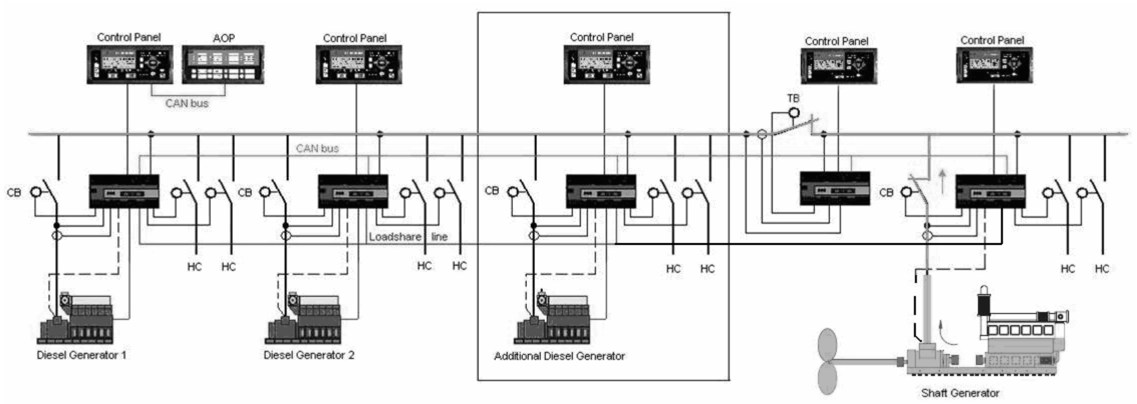
The shaft generator can be used for Power Take Home operation. In PTH operation, the binary input on terminal 50 (alarm inhibit) and the binary input on terminal 51 (PTH mode) have to be activated. By using the utility software, the protection functions for reverse power and tachometer failure can be deactivated as long as PTH mode is selected. Whenever PTH mode is selected and the shaft generator breaker is closed, the system will automatically change the plant mode to AUTO. Other plant modes will be blocked. The shaft generator breaker has to be closed (synchronised) manually, and the display unit for the shaft generator will indicate that 'PTH mode is active'.

AUTO mode (diesel operation)



The diesel generators are supplying the ship's electrical load. The load dependent start/stop function is active. The main engine can be running or shut off. The shaft generator is cut off from the electrical supply.

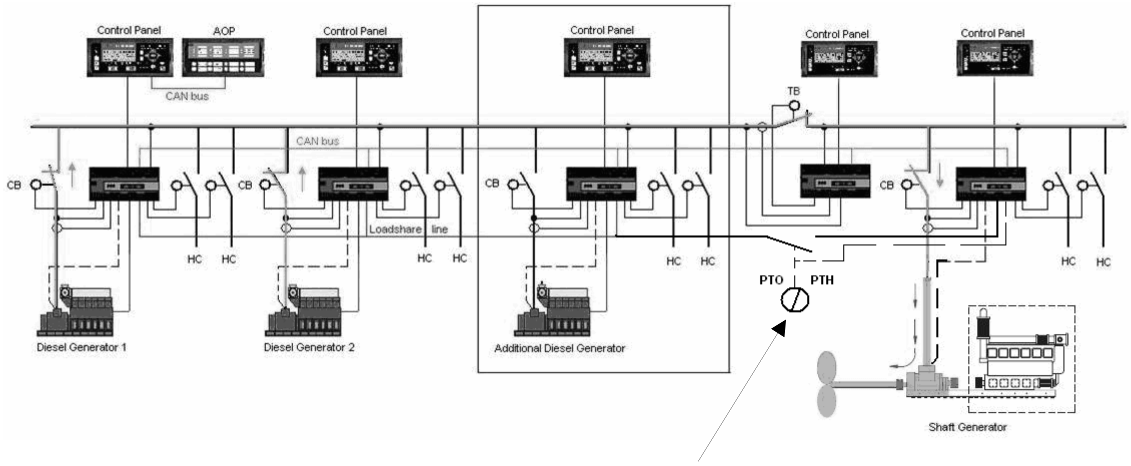
SHAFT mode (shaft generator supply)



The shaft generator is supplying the ship's electrical load. The diesel generators are stopped. The main engine is running.

PTH mode (shaft generator running as motor)

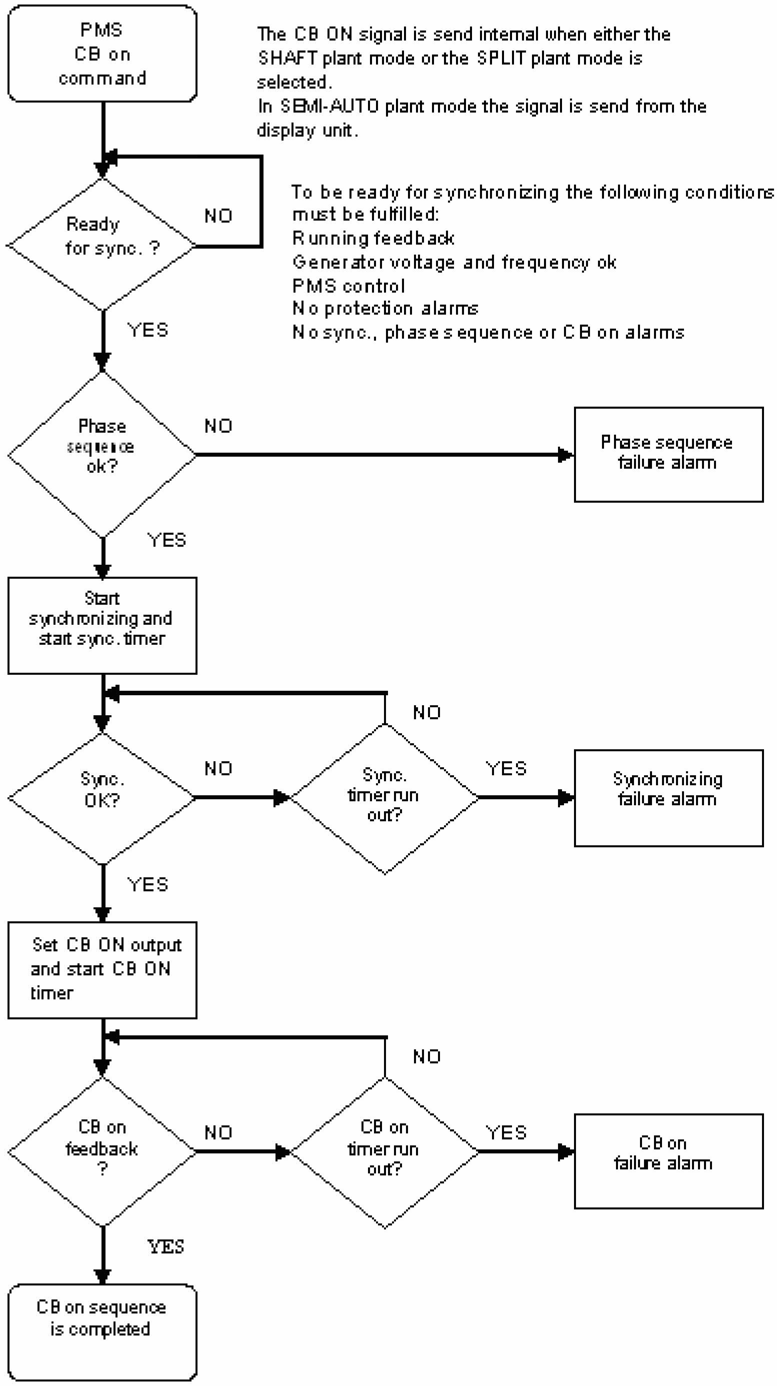
The diesel generators are supplying the ship's electrical load and run the shaft generator as engine. The load dependent start/stop function is active. The main engine is shut off. This mode is called PTH (Power Take Home) mode.



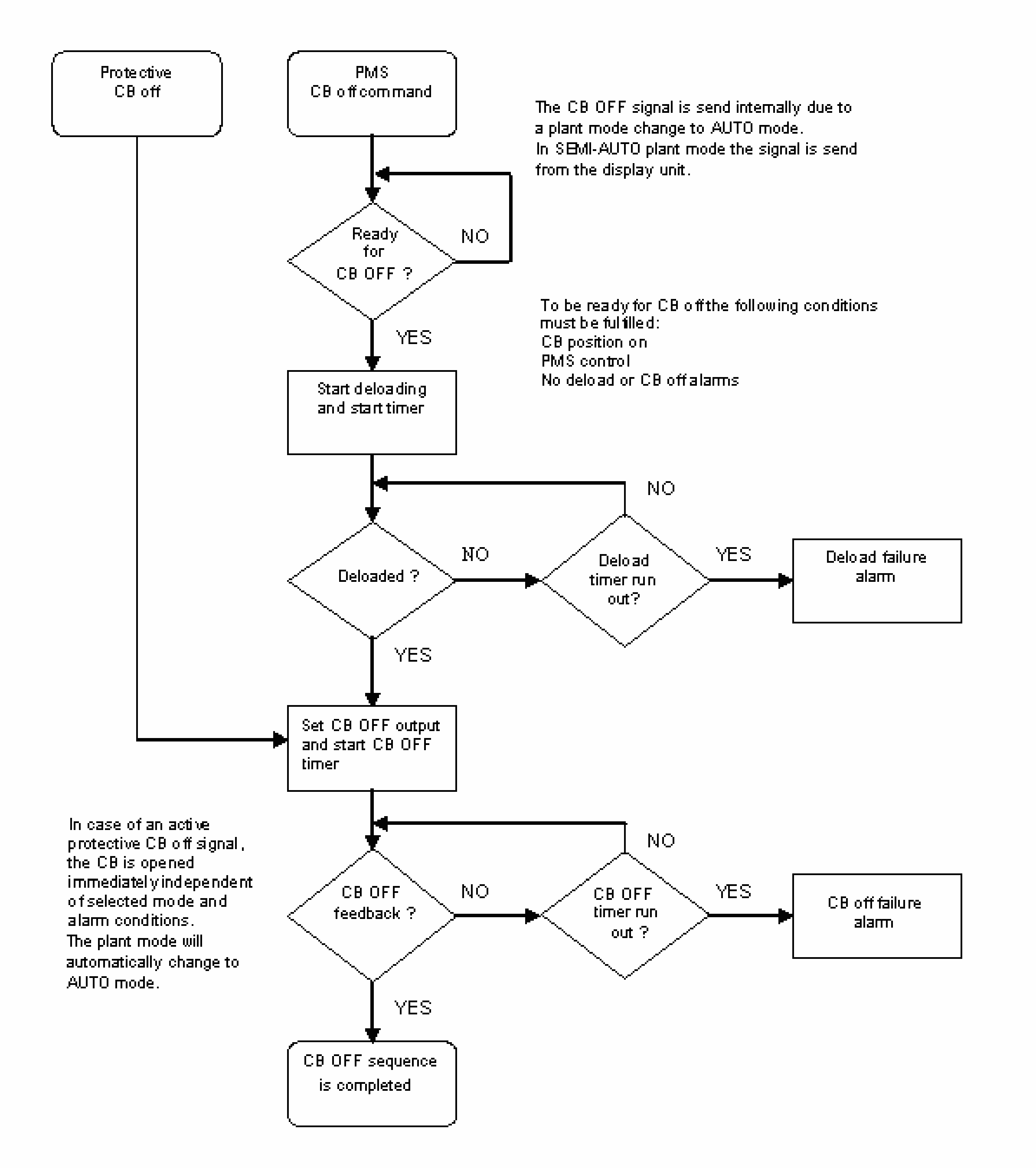
Selecting the PTH is done by means of a switch in the main switchboard. When selecting the PTH mode, a binary signal will be sent to the shaft generator unit (terminal 51). This signal is used for activating the PTH function. When the main engine is shut off, the shaft generator breaker has to be synchronised manually in the main switchboard. This can be done by using a pony motor.

To disable the protection functions like reverse power, the binary input "Alarm inhibit" on terminal 50 has to be activated at the same time. By using the DEIF utility software, alarms can be inhibited when the terminal 50 is activated. To prevent load sharing with the shaft generator unit in case of PTH mode, the analogue load share line has to be interrupted when PTH mode is selected.

CB ON sequence



CB OFF sequence



7. Shore connection

The shore connection unit has CAN bus ID no. 10. This ID no. can be adjusted in the menu system.

The shore connection unit has ID no. 10.

Protection

Digital inputs with cable supervision

The shore connection unit has 3 binary inputs **with** wire break supervision available.

The alarm text message and failure class can be changed with the DEIF utility software to fit customer demands.

SIGNAL NAME	SIGNAL TYPE	LOCATION
• VDO input 104	Binary input	Terminal 104
• VDO input 105	Binary input	Terminal 105
• VDO input 106	Binary input	Terminal 106
• COMMON (terminal 104-106)		Terminal 107

The wire break resistor is 100 Ω. No 24V DC on terminals, only potential free contacts to be used.

Cable supervision alarms

The cable supervision is separate alarms that can be enabled/disabled.

The wire break resistor has to be 100 Ω. Min.: 0.25W.

All fail classes that open the shore connection breaker automatically change the mode to AUTO.

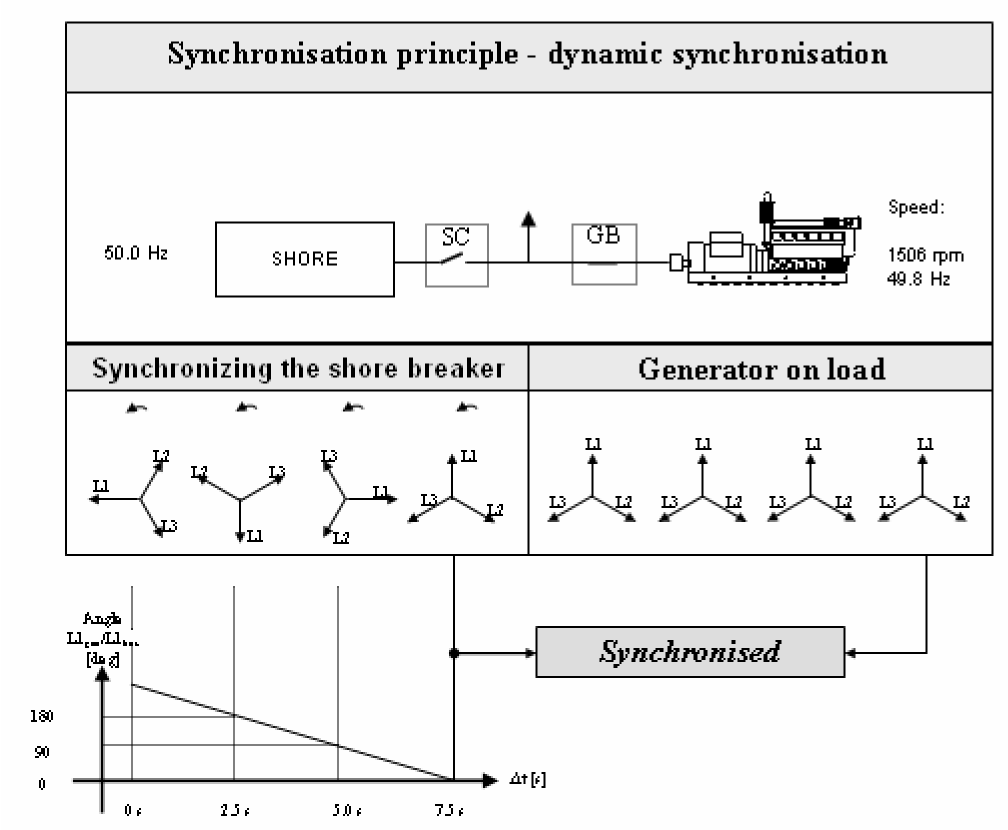
Synchronisation

For the shore connection breaker, only dynamic synchronisation is available. When shore connection breaker is being synchronised, the actual frequency control is performed by the generators, while the shore connection unit is only monitoring the difference in order to close the circuit breaker at the right time.

In the following, the term 'synchronisation' means *'synchronising and closing off the synchronised breaker'*.

Dynamic synchronisation

In dynamic synchronisation, the synchronising gen-set is running at a different speed than the shore connection. This speed difference is called *slip frequency*. Typically, the synchronising gen-set is running with a negative slip frequency towards the shore connection. This means that the shore connection under synchronisation is running with a higher speed than the generators.



In the example above, the shore connection frequency is 50.0Hz. The generator on load is running at 1506 RPM ~ 49.8Hz. This gives the shore connection a positive slip frequency of 0.2Hz. The intention of the synchronising is to decrease the phase angle difference between the two rotating systems. These two systems are the three-phase system of the shore and the three-phase system of the busbar. On the illustration above, phase L1 of the busbar is always pointing at 12 o'clock, whereas phase L1 of the synchronising gen-set is pointing in different directions due to the slip frequency.

Of course both three-phase systems are rotating, but for illustrative purposes, the vectors for the generator on load are not shown to be rotating. This is because we are only interested in the slip frequency for calculating when to release the synchronisation pulse.

When the generator is running with a negative slip frequency of 0.2 Hz compared to the shore connection, the two systems will be synchronised every 5 seconds.

tsync = 1/ (50.0 Hz – 49.8 Hz) = 5s

In the illustration above, the difference in the phase angle between the synchronising shore connection and the generator gets smaller and will eventually be zero. Then the shore connection is synchronised to the generator, and the breaker will be closed.

Close signal

The unit always calculates when to close the breaker to get the most accurate synchronisation. This means that the close breaker signal is actually issued before being synchronised (read L1 phases exactly at 12 o'clock).

The breaker close signal will be issued depending on the breaker closing time and the slip frequency (response time of the circuit breaker is 250 ms, and the slip frequency is 0.1Hz):

$$\deg_{CLOSE} = 360 * t_{CB} * f_{SLIP}$$
$$\deg_{CLOSE} = 360 * 0.250 * 0.1$$
$$\deg_{CLOSE} = 9 \deg$$

The synchronisation pulse is always issued, so the closing of the breaker will occur at the 12 o'clock position. Here the generator will rotate 9 deg. in 0.250 s.

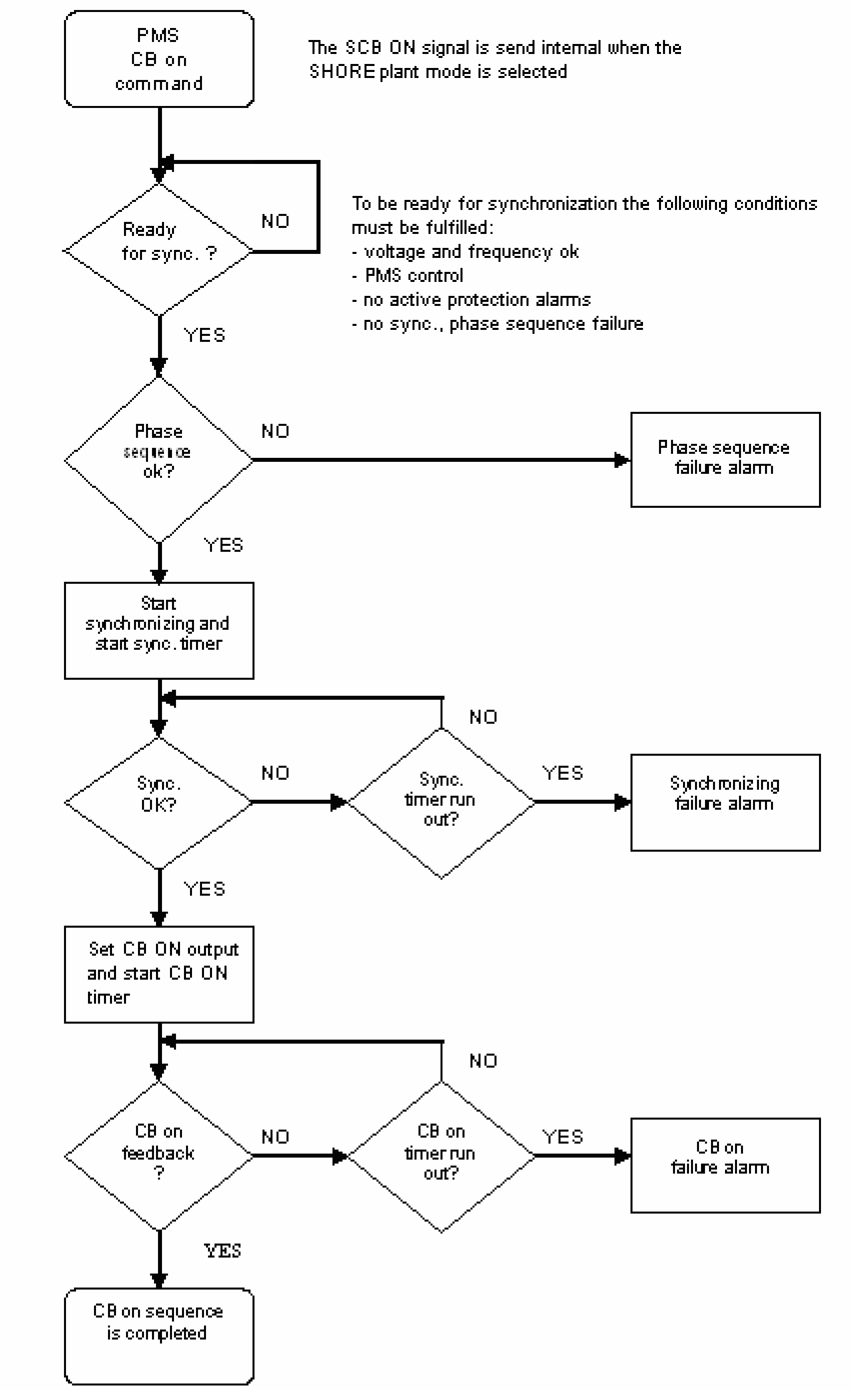
The length of the synchronisation pulse is the response time + 20 ms.

Load picture after synchronising

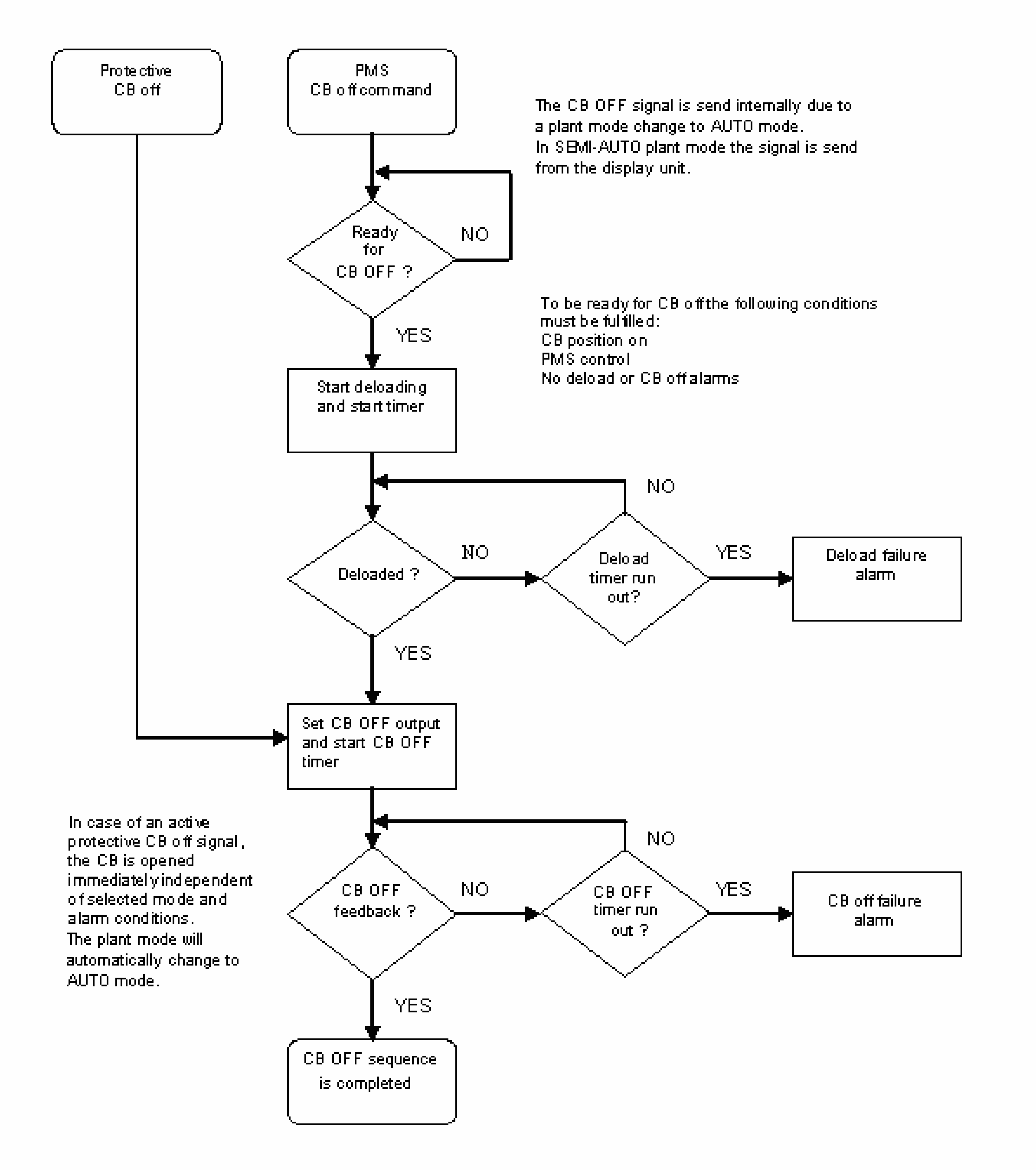
When the shore connection breaker is closed, it will take a portion of the load depending on the slip frequency.

This type of synchronisation is able to synchronise relatively fast because of the adjusted minimum and maximum slip frequencies. This actually means that when the unit is aiming to control the frequency towards its set point, then synchronising can still occur as long as the frequency is within the limits of the slip frequency adjustments.

SCB ON sequence



SCB OFF sequence



8. Bus tie breaker

The bus tie breaker unit has the CAN bus ID no. 9.

This ID no. is adjusted in menu 7530, Internal communication ID.

The bus tie breaker has ID no. 9.

Synchronisation

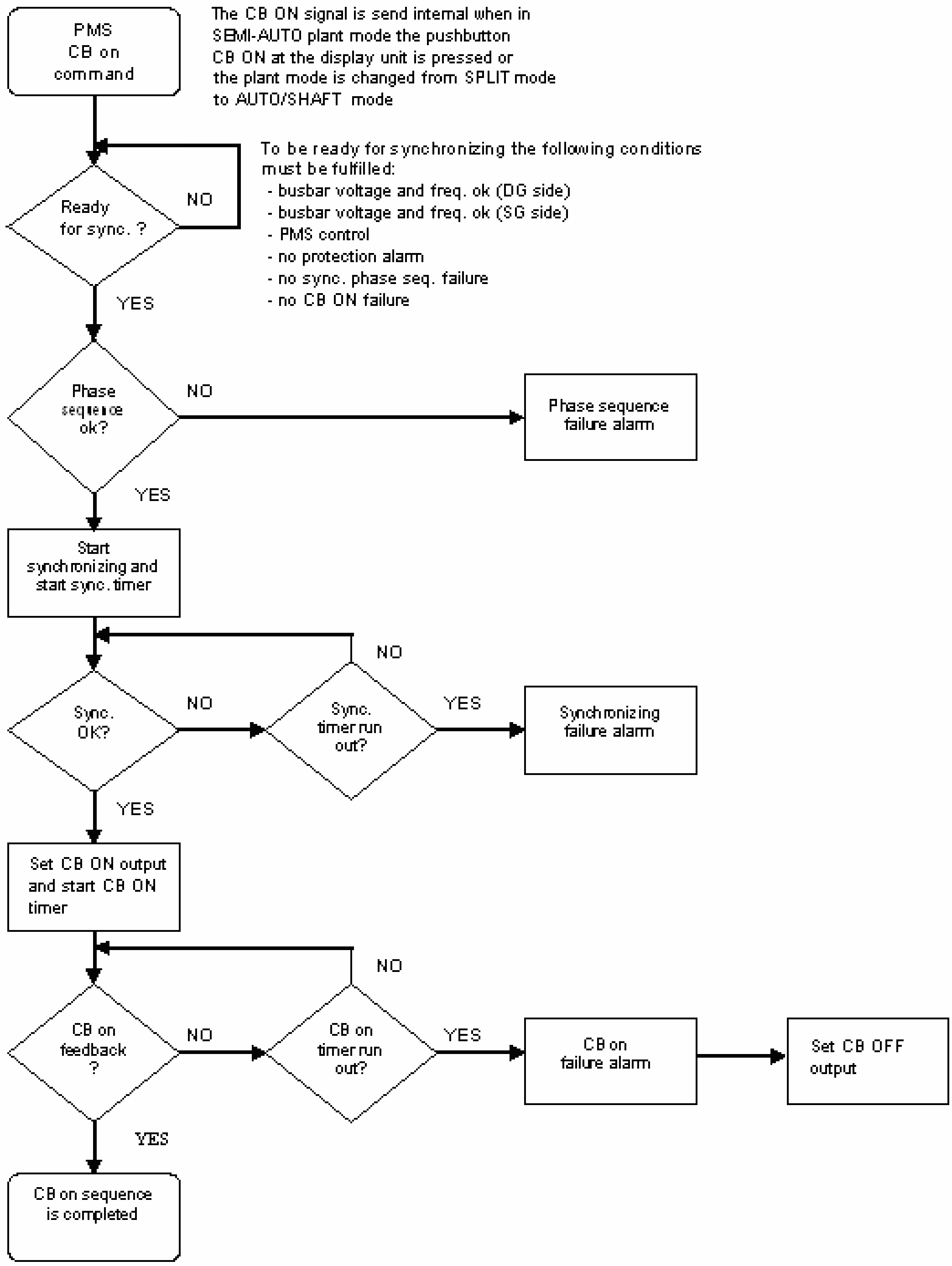
The dynamic synchronisation of the tie breaker is carried out as an oversynchronous connection of the running diesel generators at the low end of the busbar. This means the tie breaker is cut-in oversynchronous with regards to the busbar frequency at the high end of the busbar. The low end of the busbar is defined as the side of the tie breaker when DG no. 1 is connecting to the busbar; the high end is on the other side of the tie breaker where the shaft generator is connected.

The target frequency for the diesel generators is formed by the measured high end busbar frequency added with the programmed desired oversynchronous frequency. This forms reference for the frequency controlling generator sets.

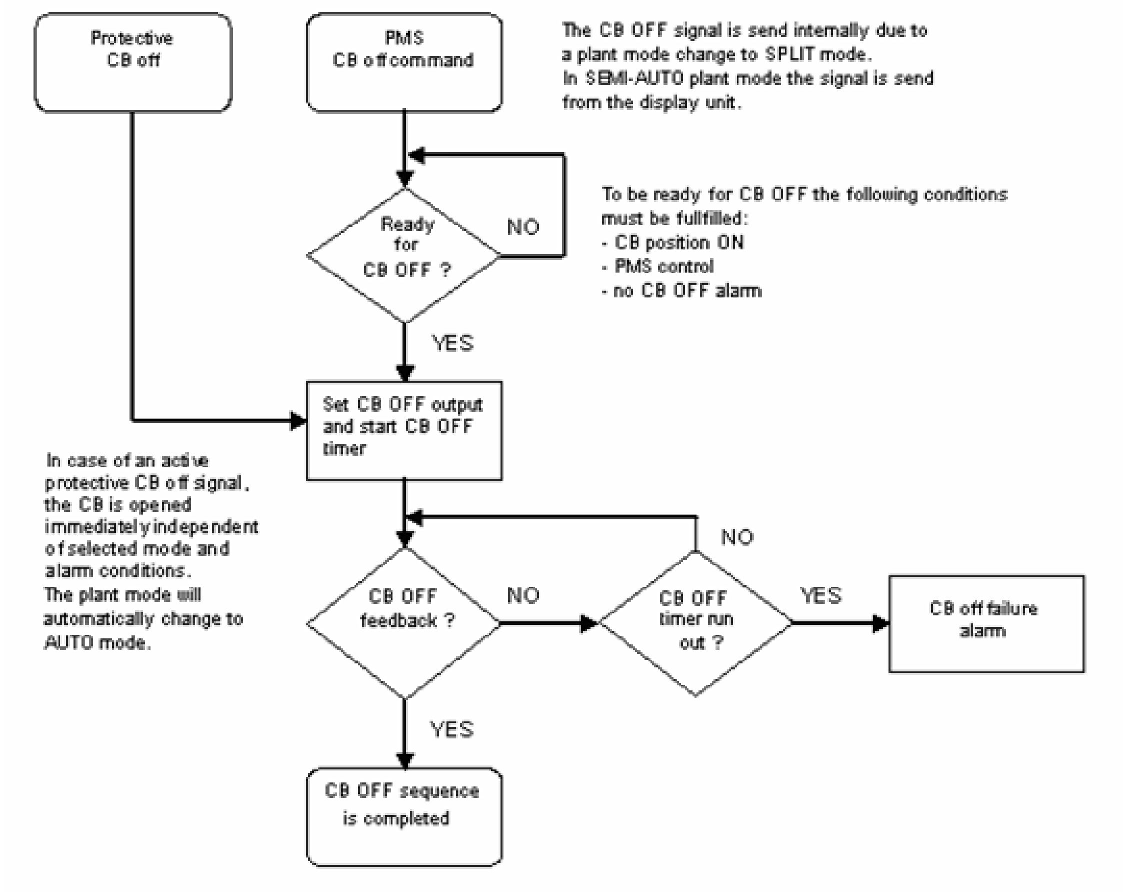
The frequency target for the dynamic synchronisation is calculated continuously during the synchronisation of the tie breaker.

The tie breaker ON signal is transmitted with compensation for the closing time of the tie breaker; the time it takes for the breaker to switch from OFF position to ON position. The extension of the command is limited in time by a timer.

CB ON sequence

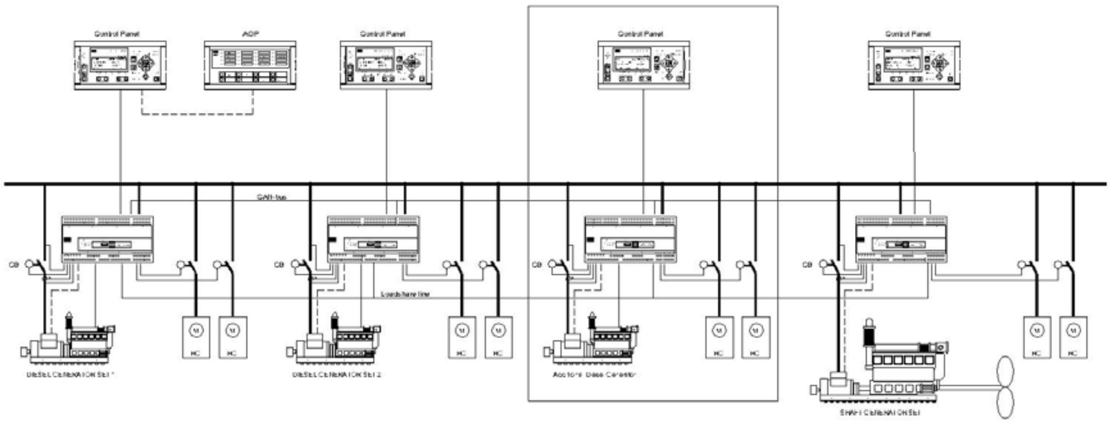


CB OFF sequence



9. Power management

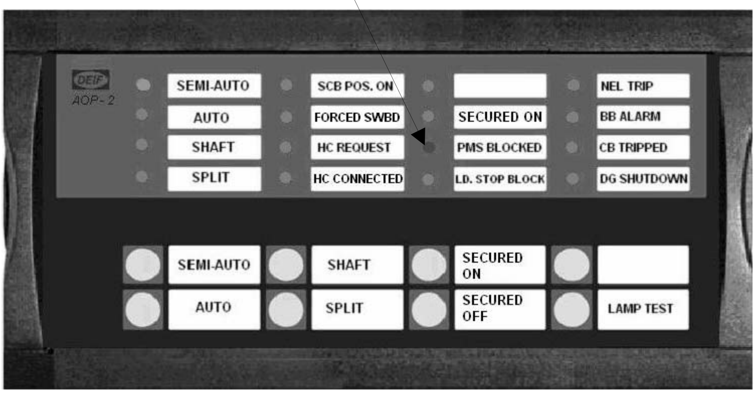
The power management software is placed in a separate controller. As standard this controller is placed in DG unit no. 1.



The power management processor handles the load dependent start/stop function, the blackout start sequence, the heavy consumer control and receives status information about the shore connection breaker and bus tie coupler.

All units are connected to each other via a CAN bus line and transport important data to the power management processor. This information will be indicated on a separate operator panel, the AOP-2. On this panel, the plant modes can be changed and it gives the operator an overview of the status of the power management functions.

A red LED "PMS BLOCKED" will be activated, if the power management system is prevented from normal operation.



Possible reasons:
- The shore connection breaker is in position ON (not system 2 shore)
- The input "FORCED SWBD" is set
- All diesel generator units are in SWBD control

When all diesel generators are in switchboard control, the LEDs for the plant modes are OFF.

Selection of diesel generator number and system type

Before setting the system in operation, the number of diesel generators and the system type must be adjusted by the operator.

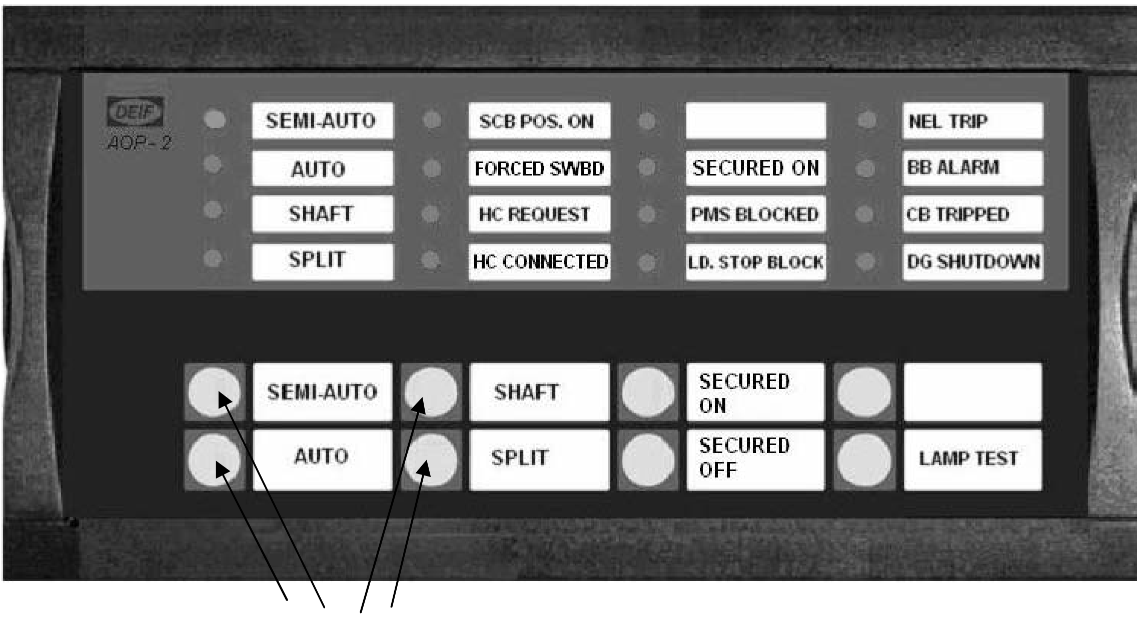
Channel number	Set point	Minimum setting	Factory setting	Maximum setting
8001	Number of DGs	2	3	8
8002	System type	1	1	3

Selection of plant modes

Dependent on the system, the following plant modes are available:

System 01:	System 02 (shaft):	System 02 (shore):	System 03:
- SEMI-AUTO - AUTO	- SEMI-AUTO - AUTO - SHAFT	- SEMI-AUTO - AUTO - SHORE	- SEMI-AUTO - AUTO - SHAFT - SPLIT

The plant mode selection will be done via the additional operator panel (AOP-2).

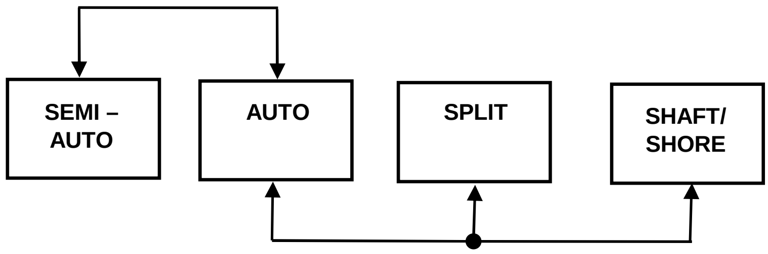


Plant mode selection

To select a plant mode, the operator simply has to press the desired plant mode push-button.

The selected plant mode will be indicated by the plant mode LED.

The plant modes are regarding to the entire system. This means that it is **not** possible to run different plant modes on different units.



The plant mode 'SEMI-AUTO' can only be selected from 'AUTO' plant mode.

SEMI-AUTO plant mode

The SEMI-AUTO plant mode is an *operator dependent* AUTO mode.

In SEMI-AUTO plant mode the automatic sequences are carried out *only on request* by the operator, via the push-buttons at display for the generator; the automatic start sequence, the GB ON sequence incl. synchronisation and load sharing, the GB OFF sequence and the automatic stop sequence.

Selection of SEMI-AUTO plant mode will have no effect on running generator sets.

The following push buttons at the display are only active when SEMI-AUTO mode is selected.

For the generator units

CB ON: The CB is synchronised. When closed, the generator will load share with the other connected generators.

CB OFF: The generator is deloaded and the CB is opened.

Start: The start sequence is carried out.

Stop: The stop sequence is carried out with cooling down. The cooling down time can be interrupted by pressing the STOP push-button again during the cooling sequence.

The system will only open the CB if the generator set is expendable at the busbar and will never open the last connected CB.

For the bus tie breaker unit

CB ON: The CB is synchronised/closed.

CB OFF: The CB is opened.

AUTO plant mode

During this fully automatic diesel generator mode called AUTO mode, the *automatic control* is carried out by all generator sets, which are selected to be under PMS control. The gen-sets are supplying both busbars, and the bus tie breaker is closed.

The power management system carries out automatic frequency and load control during the AUTOMATIC plant mode.

The busbar load is shared between the running generator sets *either as*:

• symmetrical load share
or
• asymmetrical load share

Load depending start *and* stop of the generator sets is carried out according to the actual power demand at the busbar with respect to *the programmed start/stop priority and the programmed limits for start and stop.*

The load depending start/stop function takes any running generator set which fails during engagement into consideration by starting up a stand-by generator set and substitute the defective generator set.

SHAFT GENERATOR plant mode

Selection of SHAFT plant mode is *only* accepted if:

- all running diesel generator sets are 'ready for PMS stop',
- the shaft generator is able to substitute the total power produced by the running diesel generators

and

- the plant mode is AUTO mode

The moment the SHAFT plant mode is selected, it is examined if the shaft generator voltage and frequency are within the acceptable limits.

If the shaft generator voltage and frequency are in a satisfactory condition, the dynamic synchronisation of the running diesel generator set(s) to the shaft generator is allowed to take place.

Once the synchronisation has been successfully completed, the load transfer from the diesel generators is initiated.

The SHAFT plant mode is automatically *cancelled* and AUTO mode selected if:

- a failure occurs during engagement of the shaft generator

As it may take a while before the switching from diesel generator supply to shaft generator supply of the busbar is completed, the ongoing process is indicated by a yellow SHAFT LED, as long as the process is under way. When the shaft generator is running alone, the LED turns green.

During an active SHAFT plant mode the following supervision functions are available:

- Shaft generator supervision and protection
- Load supervision

Conditional connections of heavy consumers are allowed for as long as the shaft generator is able to handle the *predicted* power demand at the busbar.

An ongoing SHAFT plant mode is automatically *cancelled* (AUTO mode selected) if:

- the shaft generator breaker is tripped,
- the tie breaker is tripped

The SHAFT plant mode is cancelled by the operator, simply by selecting the AUTO plant mode. This activates the load dependent start/stop function, which starts up sufficient stand-by generator sets in order to substitute the actual power produced by the shaft generator.

If the diesel generators are *not able* to substitute the shaft generator power, the SHAFT plant mode is automatically reselected.

Selecting the SHAFT mode coming from SPLIT mode will synchronise the bus tie breaker, deload the diesel generator(s) and open the diesel generator breaker(s).

SHORE CONNECTION plant mode

Selection of SHORE plant mode is *only* accepted if:

- all running diesel generator sets are 'ready for PMS stop',
- the shore connection is able to substitute the total power produced by the running diesel generators

and

- the plant mode is AUTO mode

The moment the SHORE plant mode is selected, it is examined if the shore voltage and frequency are within the acceptable limits.

If the shore voltage and frequency are in a satisfactory condition, the dynamic synchronisation of the running diesel generator set(s) to the shore is allowed to take place.

Once the synchronisation has been successfully completed, the load transfer from the diesel generators is initiated.

The SHORE plant mode is automatically *cancelled* and AUTO mode selected if:

- a failure occurs during engagement of the shore connection

As it may take a while before the switching from diesel generator supply to shore supply of the busbar is completed, the ongoing process is indicated by a yellow SHORE LED, as long as the process is under way. When the shore connection is supplying alone, the LED turns green.

During an active SHORE plant mode the following supervision functions are available:

- Shore connection supervision and protection
- Load supervision

An ongoing SHORE plant mode is automatically *cancelled* (AUTO mode selected) if:

- the shore connection breaker is tripped,

The SHORE plant mode is cancelled by the operator, simply by selecting the AUTO plant mode. This activates the load dependent start/stop function, which starts up sufficient stand-by generator sets in order to substitute the actual power produced by the shore connection.

If the diesel generators are *not able* to substitute the shore connection power, the SHORE plant mode is automatically reselected.

SPLIT plant mode

Selection of SPLIT plant mode is *only* accepted if:

- the bus tie breaker, the shaft generator and the DGs are in PMS control

and

- the plant mode is AUTO mode

The SPLIT plant mode is dividing the switchboard into two parts.

Coming from AUTO mode and selecting the SPLIT mode, the shaft generator breaker will be closed. A few seconds after the shaft generator breaker is closed, the bus tie breaker between the SG busbar and the DG busbar will open. The generators are in automatic control, which means that the load depending start/stop limits are active.

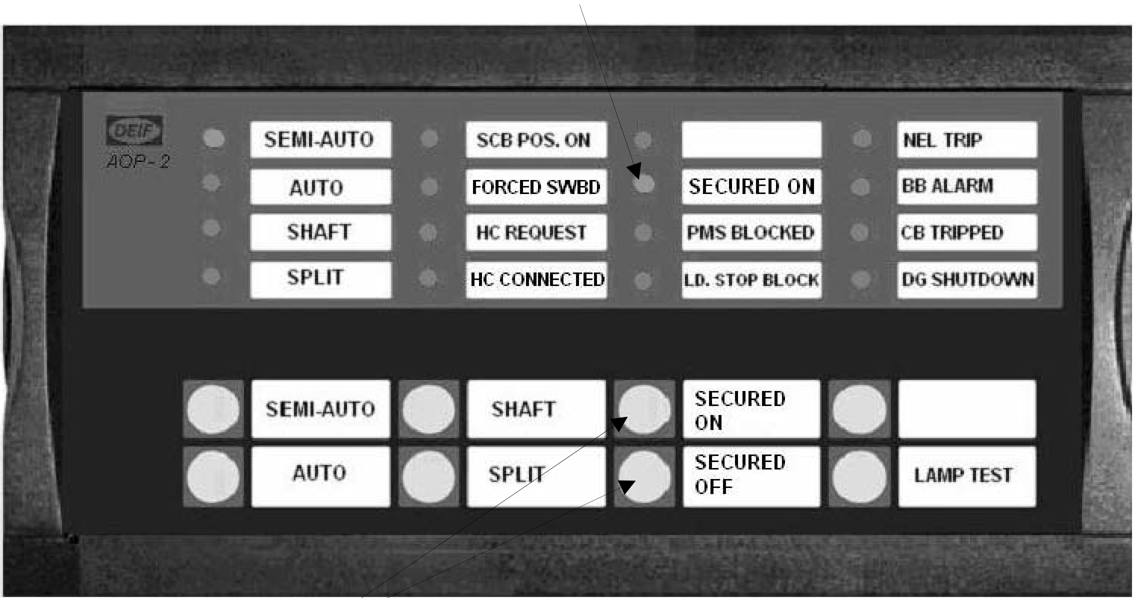
Coming from SHAFT mode and selecting the SPLIT mode, the diesel generator with the first priority will start and connect to the busbar. A few seconds after the generator breaker is closed, the bus tie breaker between the SG busbar and the DG busbar will open. The diesel generators will run automatically with load dependent start/stop.

In this way the SPLIT plant mode ensures a totally separated supply on each busbar. One common use is the manoeuvre situation.

As it may take a while before all the conditions for the split mode are fulfilled, the ongoing process is indicated as the LED for the 'SPLIT mode' is flashing yellow, until the tie breaker has opened. Then the LED turns green.

Secured function

For additional safety, the operator is able to select "SECURED ON" on the AOP-2.



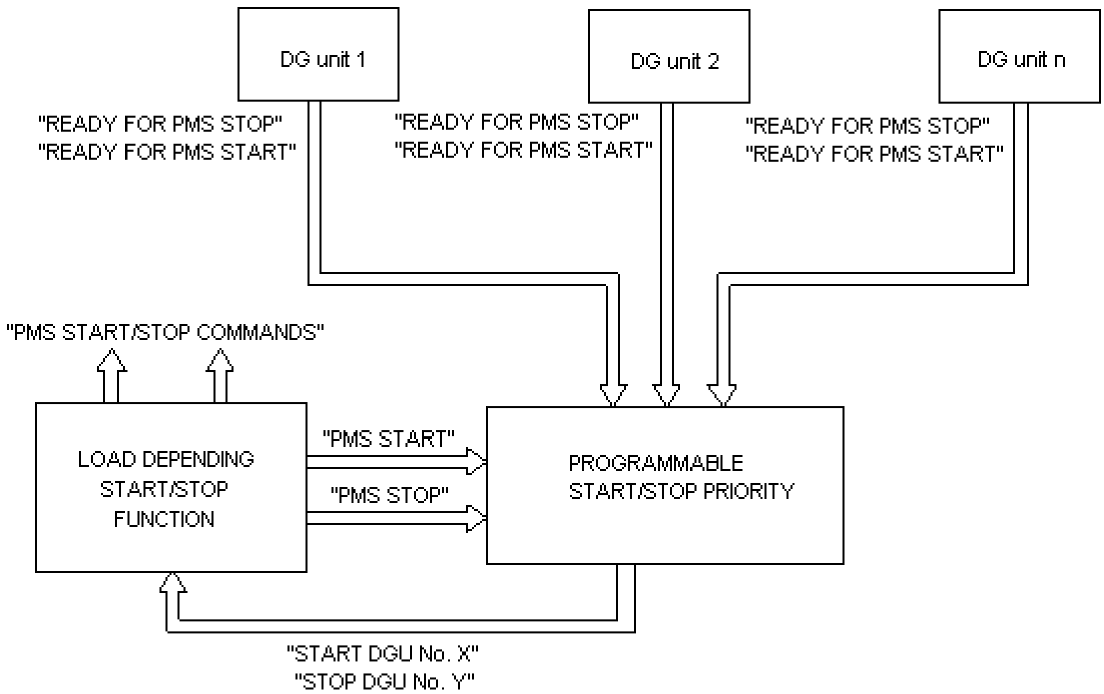
By activating the "SECURED" function an additional diesel generator will start up and connect to the busbar independent of the load conditions. This function is **only** active in AUTO plant mode or SPLIT plant mode.

Automatic PMS functions

x = active - = inactive (1) = Push-button activated	SWBD CONTROL	PMS CONTROL			
		PLANT MODES			
		SEMI-AUTO MODE	AUTO MODE	SPLIT MODE	SHAFT/SHORE MODE
AUTOMATIC PMS FUNCTIONS					
Load depending start/stop	-	-	x	x	-
Selection of start/stop priority	-	-	x	x	-
Frequency control	-	x	x	x	-
Symmetrical load share	-	x	x	x	-
Asymmetrical load share	-	-	x	x	-
Blackout start	-	x	x	x	-
Shore connection supervision	x	x	x	x	x
Conditional connection of heavy consumers	-	x	x	x	x
GENERATOR SET FUNCTIONS					
Automatic start sequence	-	(1)	x	x	-
CB ON sequence	-	(1)	x	x	x
Frequency/load control	-	x	x	x	x
Manual control of freq./load	x	-	-	-	-
CB OFF sequence	-	(1)	x	x	
Automatic stop sequence	-	(1)	x	x	-
GENERATOR SET PROTECTION					
Internal system supervision	x	x	x	x	x
Engine supervision	x	x	x	x	-
Busbar supervision	x	x	x	x	x
Generator protection	x	x	x	x	x
Short circuit protection	x	x	x	x	x
Trip of non essential load groups	x	x	x	x	x

Start priority selection

The start priority selection can be done manually or automatically concerning the running hours. Depending on the *programmed priority sequence* and the operational status of the generator sets, the start priority function continuously designates each generator set with a *PMS start priority* and a *PMS stop priority* respectively.



The illustration above shows the operating principle for determination of the start/stop priority.

The operator has three possibilities to program the first start priority:

1. Manually from the display of the PM unit
2. Manually via the first priority push-button on each DG unit
3. Automatically regarding the accumulated running hours for each generator set.

The **manual selection** from the display of the PM unit is done by programming the start/stop priority sequence for all generator sets through the display unit corresponding to the PM unit.

Example:
Start priority is 1-2-3-4. The new priority should be 3-2-4-1.

- menu 8052 (1^{st} Prior DGno.) and select 3
- menu 8053 (2^{nd} Prior DGno.) and select 2
- menu 8054 (3^{rd} Prior DGno.) and select 4
- menu 8055 (4^{th} Prior DGno.) and select 1

When the selection is done, the menu 8051 (transmit) has to be activated to send the new values to the calculator.

The calculator is supervising the priority sequence. This means if the operator selects a priority sequence like 1-2-2-4 (two generators with the same priority number), the calculator will ignore the new setting and activate the old settings.

The **manual selection** via the first priority push-button is simply done by pressing the **'1st PRIOR'** push-button for the generator that is to get the first start priority.

The **1st PRIOR** LED is active at the display unit of the diesel generator with the highest priority.

The **1st Standby** LED is active at the display unit of the **stand-by** diesel generator with the highest priority. This means that the 1st Standby LED is only activated at the display of a diesel generator which is not running and which is ready for PMS start.

The example below shows how the start priority changes, if the operator presses the '1st PRIOR' push-button at the display unit corresponding to diesel generator no. 4:

The start priority sequence *before* as read-out on the display of the power management unit:

2 - 3 - 1 - 4 meaning

- DG no. 2 is designated with *start* priority no. 1 (to be started first)
- DG no. 3 is designated with *start* priority no. 2 (1st Standby when not running)
- DG no. 1 is designated with *start* priority no. 3
- DG no. 4 is designated with *start* priority no. 4 (to be started last)

Then the push-button '1st PRIOR' on the display unit corresponding to DG no. 4 is pressed! The start priority sequence *after* as read-out on the CP:

4 - 2 - 3 - 1 meaning:

- DG no. 4 is designated with *start* priority no. 1 (to be started first)
- DG no. 2 is designated with *start* priority no. 2 (1st Standby when not running)
- DG no. 3 is designated with *start* priority no. 3
- DG no. 1 is designated with *start* priority no. 4 (to be started last)

The load depending start/stop function will subsequently rearrange the running generator sets according to the new start priority.

The **automatic** designation of the first start priority ensures the operating hours (running hours) are equally distributed at all generator sets in the power plant.

The total accumulated running hours for each generator set are counted and stored by the corresponding DG unit in the register 'RUNNING HOURS'.

The operator is able to activate or deactivate the automatic designation of first start priority and can adjust the time interval in which the running hours are checked.

When the automatic designation of first start priority is activated, the first start priority is designated to the generator set with the lowest recorded engine running hours.

The example below shows the operating principles of the automatic designation of first priority.

The start priority is (2 - 3 - 1 - 4) *before* the automatic designation function is carried out:

- DG unit no. 2 is designated with *start* priority no. 1; 'RUNNING HOURS' = 12550
- DG unit no. 3 is designated with *start* priority no. 2; 'RUNNING HOURS' = 12555
- DG unit no. 1 is designated with *start* priority no. 3; 'RUNNING HOURS' = 10500 *)
- DG unit no. 4 is designated with *start* priority no. 4; 'RUNNING HOURS' = 12560

The start priority sequence *after* the automatic designation function is carried out (1 - 2 - 3 - 4):

- DG unit no. 1 is designated with *start* priority no. 1; 'RUNNING HOURS' = 10500 *)
- DG unit no. 2 is designated with *start* priority no. 2; 'RUNNING HOURS' = 12550
- DG unit no. 3 is designated with *start* priority no. 3; 'RUNNING HOURS' = 12555
- DG unit no. 4 is designated with *start* priority no. 4; 'RUNNING HOURS' = 12560

*) PPM unit no. 1 has the lowest number of accumulated running hours.

Load dependent start/stop

The load dependent start/stop function is active when the AUTO plant mode is selected and the shore connection breaker is not closed. The start/stop function transmits a PMS start/stop command, which is based on a calculation of how many generator sets are needed in order to satisfy the actual power demand at the busbar.

The PMS start/stop command causes the individual generator sets to carry out the start/stop according to the programmed start priority. The calculation of the load depending PM start/stop command is based on a comparison of the programmed start/stop limit.

The load dependent start/stop function can be selected as rated power set point (P), apparent power set point (S) and as nominal value or percentage value.

Load dependent start

Independent of choice (P [kW] or S [kVA]) the functionality is basically identical; therefore the principle explanation of the functionality will be done for the load dependent start function with selected rated power (P) value.

The load dependent start function point is the lowest acceptable available power for the plant. When this value is reached, the next generator will be started.

The available power is calculated by the nominal power of all connected generators minus the used power on the busbar.

1.) Rated power (P) set point: P(avail.) = P(nom) – P(used)

The apparent power set point is typically selected, if connected load has an inductive character and the power factor is below 0.7.

2.) Apparent power (S) set point: S(avail.) = S(nom.) – S(used)

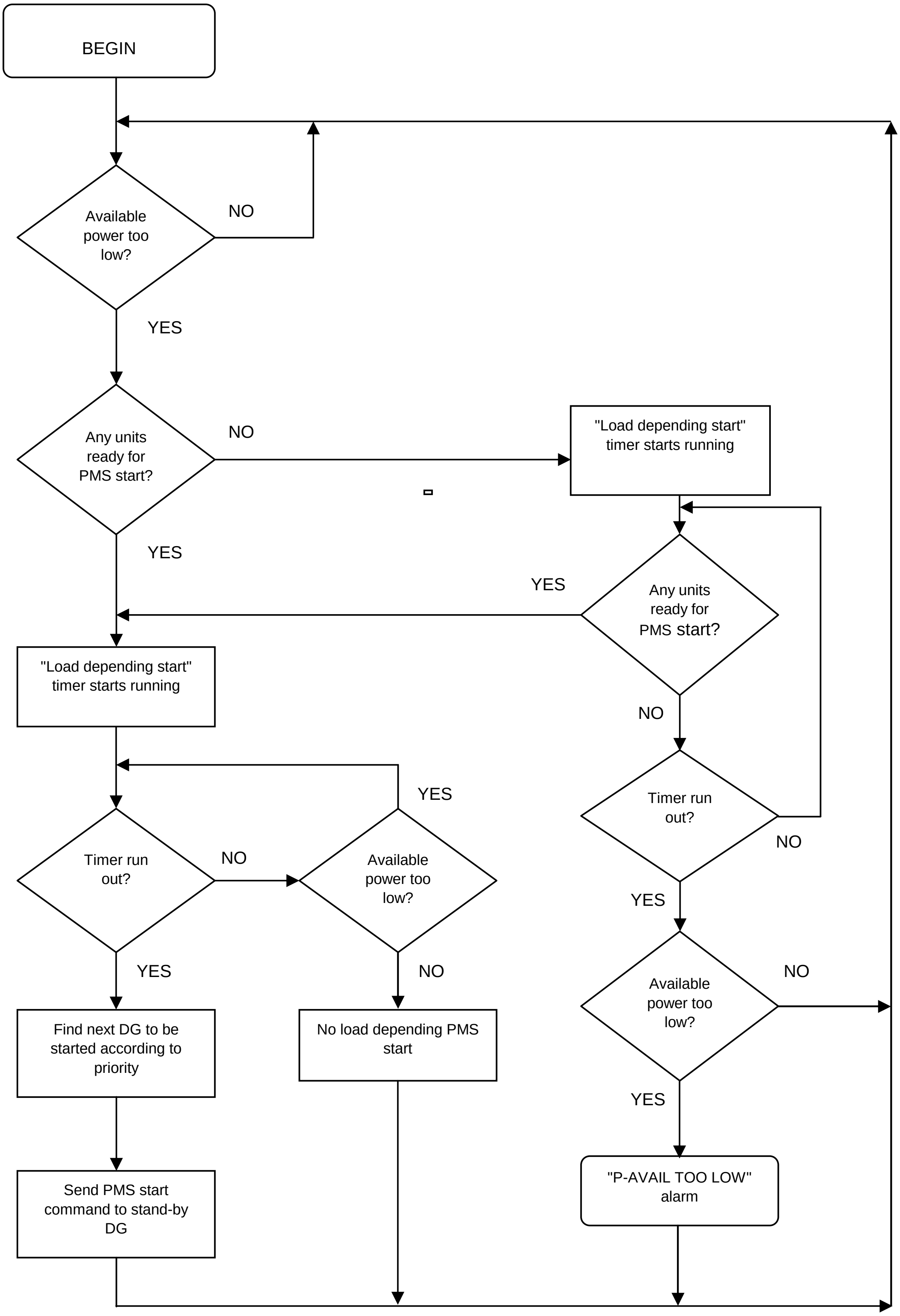
The load dependent start function will:

- check the start priority and
- send a start command to the next available generator in the start priority order

The load dependent PMS start command is transmitted time delayed in order to avoid unnecessary start of stand-by generator sets due to brief load variations.

An active load depending start timer is indicated as information message on the display of the master unit.

Load dependent start flow chart



Load dependent stop

The load dependent stop point is the highest acceptable available power value for the plant. If this value is reached or exceeded, a stop command will be sent to the running diesel generator, which is next in the stop order dependent on the start/stop priority

The operator is able to adjust the following set points and timer, by which the transmission of the load depending PMS start command is controlled:

The load dependent stop value in kW or kVA must be above the start value.
The load dependent stop value in % must be below the start value.

The load dependent stop function can be blocked by the following two functions:

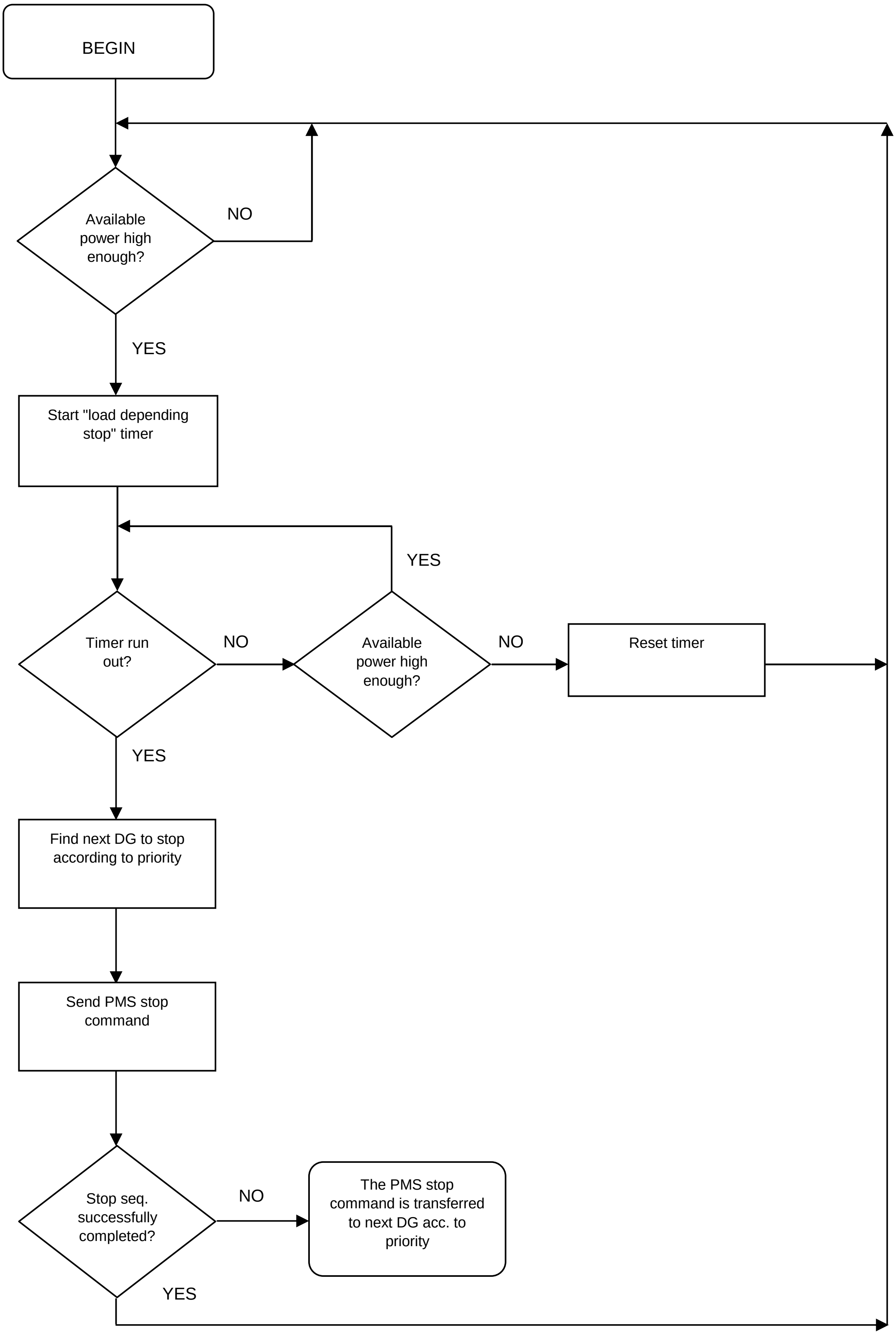
- Via the set point (8035) whenever a heavy consumer is connected to the busbar,

or

- whenever the binary input 'load dependent stop block' (term. 53 on DG 1) is set

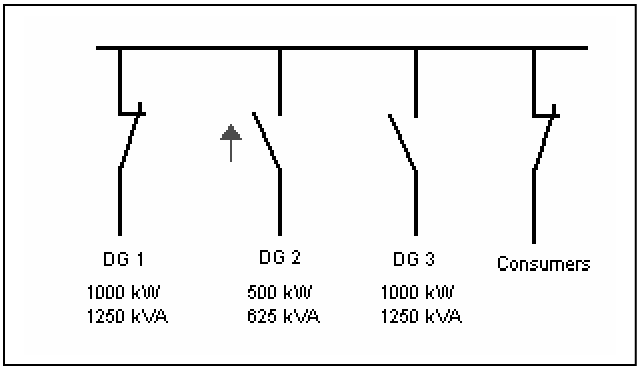
The load dependent stop blocking function via the set point is automatically ignored, if there is **not** a heavy consumer (HC) connected to the busbar. The load dependent stop blocking function via the binary input will be active as long as the input is set.
An active load depending stop timer is indicated as information message on the display of the master unit.

Load dependent stop flow chart



Load dependent start/stop calculations

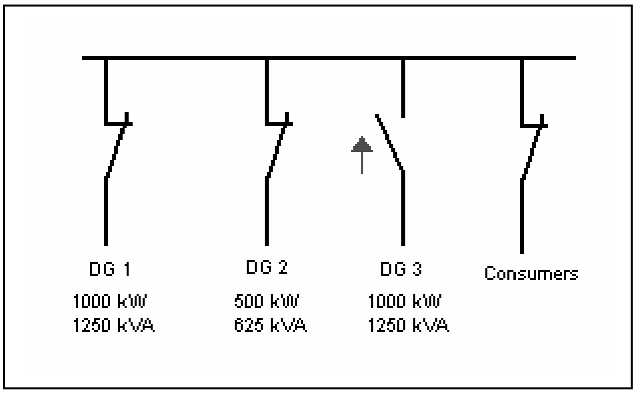
Example for the load dependent start function:



Starting conditions
The DG no. 1 is connected; DG no. 2 and DG no. 3 are in stand-by. Load dependent start set point: 90%.
The priority is 1-2-3.

When the diesel generator no. 1 is loaded with more than 90% of its nominal power, the load dependent start timer starts running.

After the timer has been running out, the diesel generator no. 2 will start up and connect to the busbar.

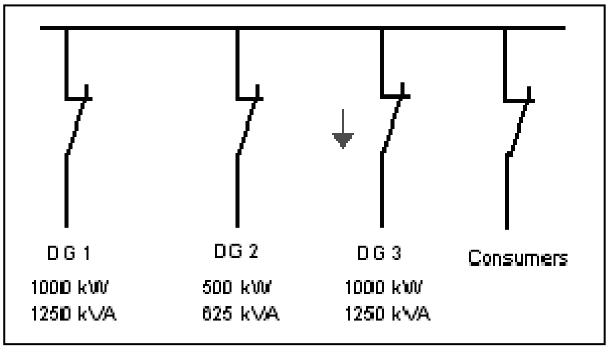


Starting conditions
The DG no. 1 and DG no. 2 are connected; DG no. 3 is in stand-by.
Load dependent start set point: 90%.
The priority is 1-2-3.

When the consumed power on the busbar is above 90% of the available power, the load dependent start timer starts running.

After the timer has been running out, the diesel generator no. 3 will start up and connect to the busbar.

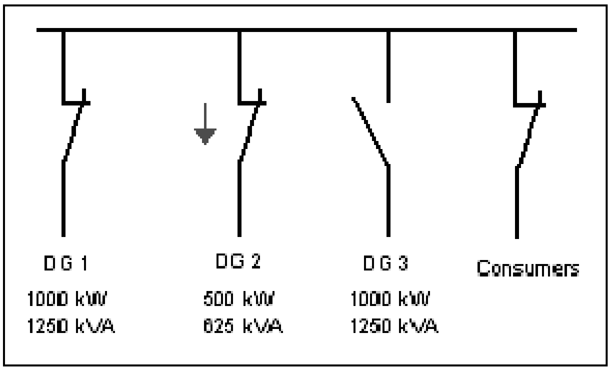
Example for the load dependent stop function with factory settings:



Starting conditions
The DG no. 1, DG no. 2 and DG no. 3 are connected. Load dependent stop set point: 70%.
The priority is 1-2-3.

When the consumed power on the busbar is decreasing below 70% of the available power of DG no. 1 and DG no. 2, the load dependent stop timer starts running.

After the timer has been running out, the diesel generator no. 3 will deload, open the breaker and stop. The DG no. 1 and DG no. 2 will be loaded with 70% of their nominal power.



Starting conditions
The DG no. 1 and DG no. 2 are connected; DG no. 3 is in stand-by. Load dependent stop set point: 70%.
The priority is 1-2-3.

When the consumed power on the busbar is decreasing below 70% of the nominal power of DG no. 1, the load dependent stop timer starts running.

After the timer has been running out, the diesel generator no. 2 will deload, open the breaker and stop. The DG no. 1 will be loaded with 70% of its nominal power.

After the timer has been running out, the diesel generator no. 2 will deload, open the breaker and stop.

Blackout start

The PPM system is able to handle two different kinds of blackout functions in the system, dependent on the failure situation and unit status. The blackout function is active in all plant modes.

1. Blackout with PMS functions in operation
If the power management unit is working and the internal CAN communication between all the other units is without any failure, the blackout handling is controlled by the power management unit.

2. Blackout with blocked PMS functions
If the internal CAN communication between the units is broken or the power management unit is out of order, the blackout start function will be handled locally. To be able to handle the secondary blackout function, a predefined wiring is needed in order to have the relevant information.

Blackout with PMS functions in operation

The power management blackout sequence is started once the power management unit receives an individual 'dead busbar' signal over the internal CAN communication from all units in the system.

The operator is able to adjust the following parameters:

- Amount of diesel generator sets to start in case of blackout
- Automatic change of plant mode to either SEMI-AUTO or AUTO mode
- Start and connection attempts in case of short circuit and blackout

The individual 'dead busbar' internal signal is transmitted, when a unit continuously has registered the following conditions during a one second delay:

- The largest measured busbar phase-phase voltage (U_{L-L}) is below 20% of nominal value
- The corresponding generator breaker is in OFF position
- *No/one short circuit alarm* is active in the unit (selectable)

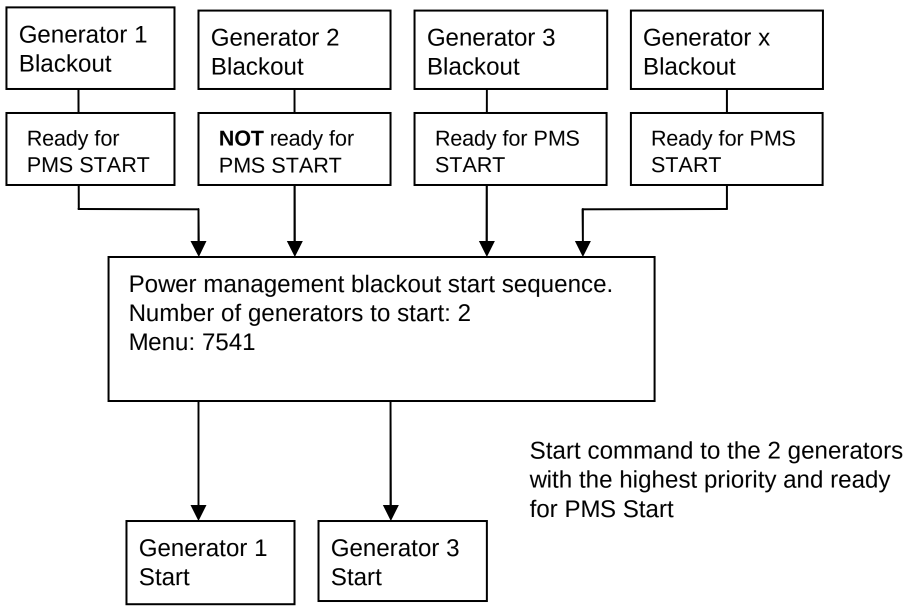
An unacknowledged short circuit alarm at any unit can block the entire blackout start sequence (depends on value selection).

In such cases the operator must acknowledge the short circuit alarm in order to enable the blackout start sequence.

If one or several of the above-mentioned initiating conditions disappear, *the 'dead busbar' detection is immediately disabled*.

When the blackout has been established, the blackout start sequence will start.

Activation of the blackout start sequence is only possible, if at least one of the generators is in PMS control and 'ready for PMS start'.



The blackout start sequence will activate the automatic start sequence, starting the generators with the highest priority and the second highest start priority (if selected). Which at the same time are 'ready for PMS start'.

If two generators have been selected, then the functionality is as follows:

1) The DG unit which first obtains normal running feedback and normal generator voltage/ frequency will close the breaker immediately (after receiving an acknowledge signal from the power management unit).

   - If this does not result in closing of the generator breaker, the other blackout started generator set will be requested to close this breaker without synchronisation.

2) The second blackout started generator will initiate synchronisation of the generator breaker approx. 2 s after satisfactory voltage and frequency has been detected at the busbar.

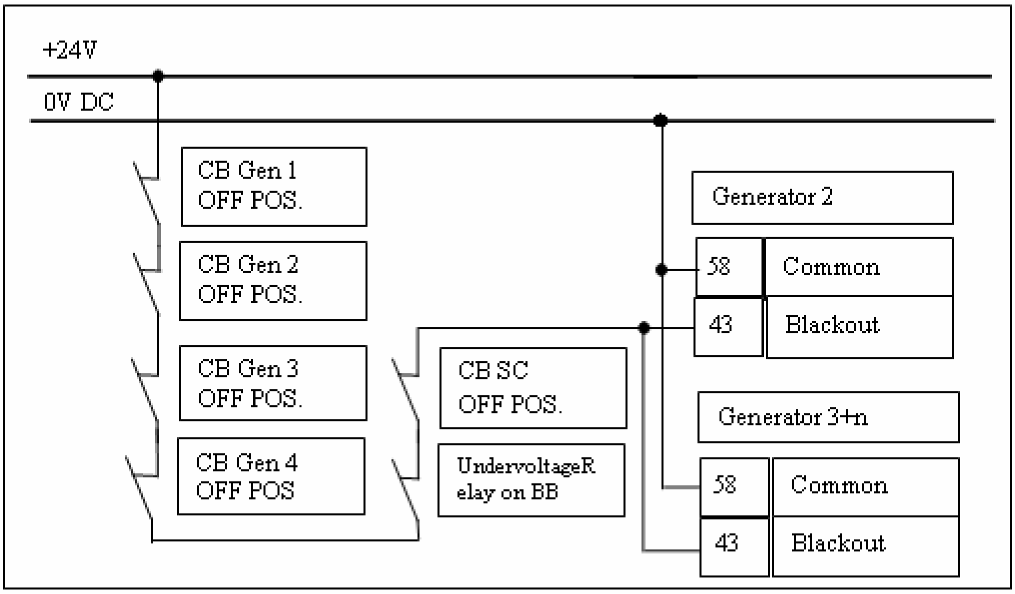
3) *If any of the two chosen generator sets* fails during the start sequence, the power management start command is transferred to the next stand-by generator, as long as the blackout situation is present.

4) *When one generator set is successfully connected to the busbar*, the blackout function is considered to be completed, and the system will switch back to 'normal' operation again.

If the power management unit is unable to communicate with a unit (indicated by a communication alarm message), the signal from the defective unit is not required in order to initiate the blackout start sequence.

Blackout with blocked PMS functions

In case of a failure in the unit (generator 1) that handles the power management functions, the backup blackout function will automatically be activated. As there is in this case no system information available from the power management unit, the blackout function will require an external wire loop in order to verify that all circuit breakers are in OFF position and an external undervoltage detection also detects a blackout, in order to start the generators.



Terminal description

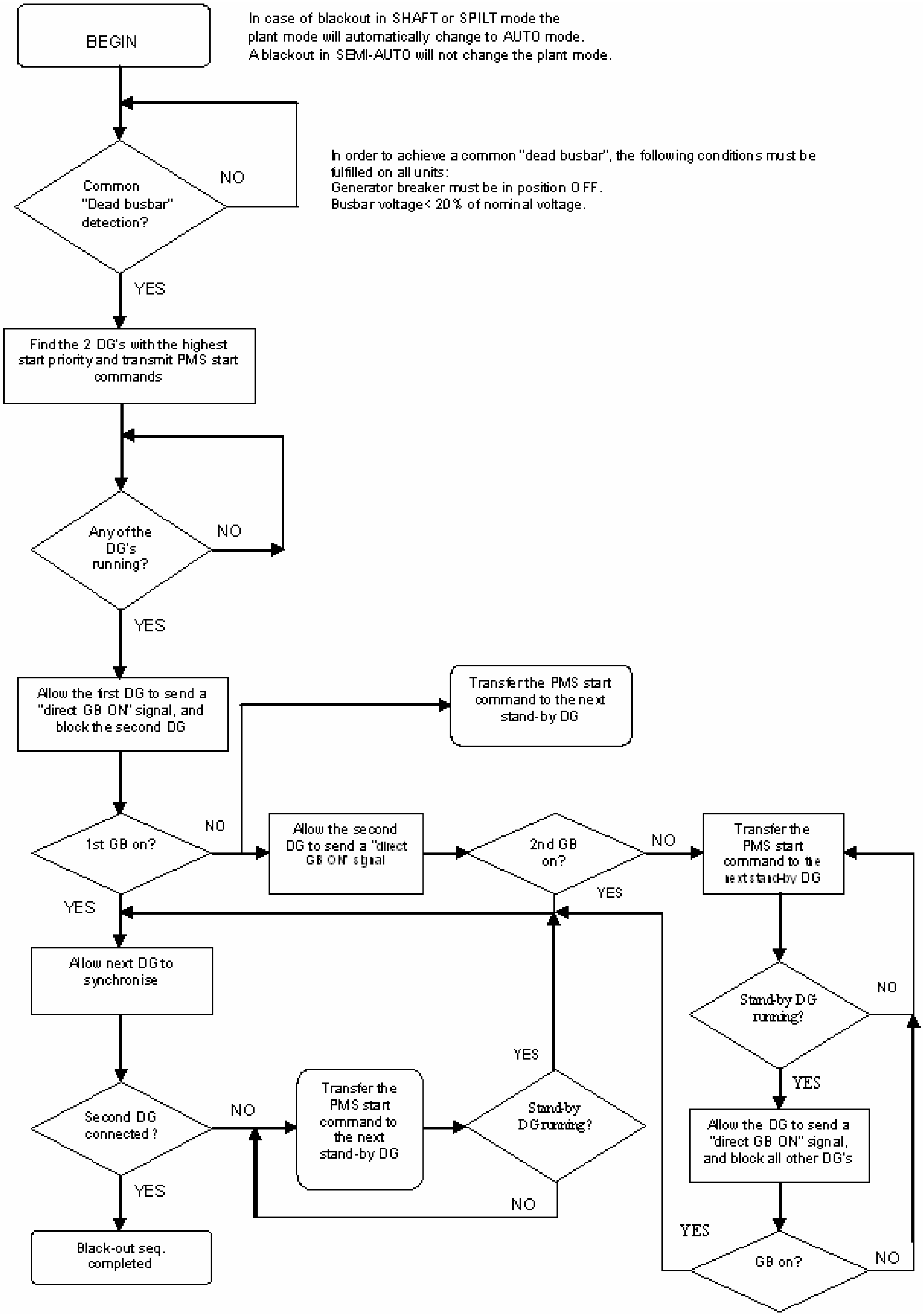
43	Binary input	Blackout	Blackout input from external relay. (All breakers in position OFF).

The backup blackout start will start up and connect the DG no. 2.

If DG no. 2 is not available, DG no. 3 will start up and connect to the dead busbar.

In case of CAN bus error, the local diesel generator is unable to know the status of the other generators. To prevent simultaneous connection of two generator breakers at the same time, only diesel generator no. 2 will start up and connect to the dead busbar. If this generator is not available the blackout starting sequence will be interrupted.

Blackout start flow chart

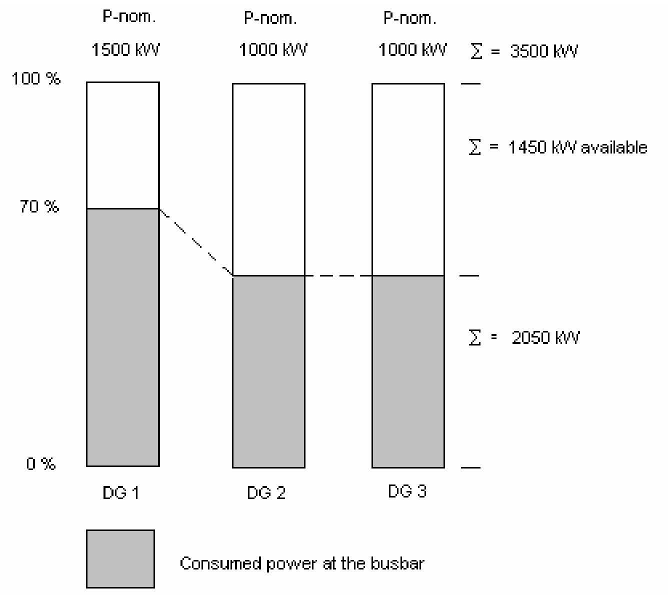


Asymmetrical load sharing

An activated asymmetrical load share function will be indicated at the display unit by a green '**Base load**' LED and the user information 'FIXED POWER' is shown in the display.

The asymmetrical load share function is *only* active when 2 or more generators are running in parallel and the plant mode is AUTO. The base load is carried out by the generator with the first priority, when selected by the operator.

If the load conditions do **not** allow asymmetrical load sharing, symmetrical load sharing will automatically be selected. This could be caused by either too little consumed power (under the set point level) or too much consumed power (overload situation). When asymmetrical load share is selected, the chosen unit will produce a programmable fixed base load.



Asymmetrical load share carried out with the base load set to 70%.

Load variations are handled by all other connected generator set(s), except the one carrying out base load. Load variations are shared symmetrically.

The operator is able to adjust the following set points, by which the asymmetrical load share function is controlled:

Automatic cancellation of the asymmetrical load share function

The asymmetrical load share is automatically cancelled by the power management unit, if:

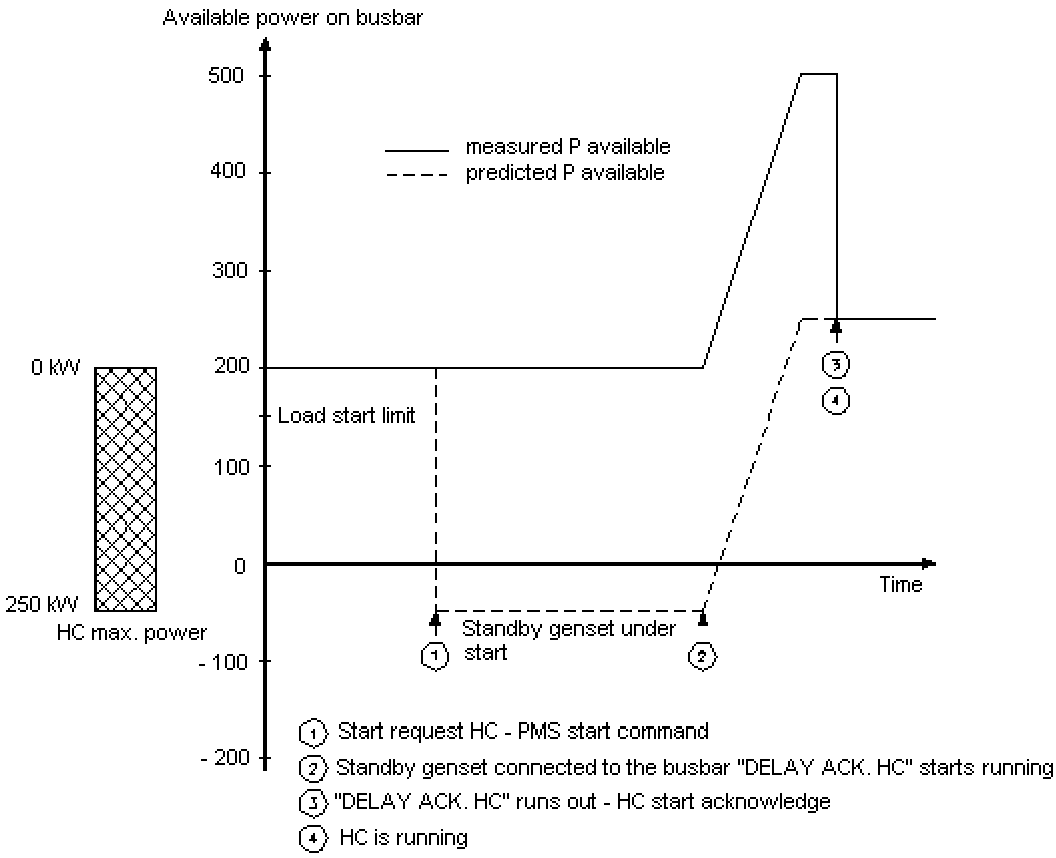
- the 'base load' generator set produces more than 90% of the total busbar load
- the load on one of the additional generator sets becomes less than 2% of nominal power
- the load on one of the additional generator sets becomes higher than 98% of nominal power
- a blackout situation is detected
- the number of generator sets on the busbar under PMS control is below two
- the plant mode changes from AUTO mode

A cancelled base load function from the power management unit due to one of the above-mentioned functions will be indicated by:

- a *yellow* '**BASE LOAD**' LED

Connection of heavy consumers

The conditional connection of **H**eavy **C**onsumers function is able to handle two heavy consumers (HCs) per generator. When a heavy consumer is requested, the function for conditional connection of heavy consumers reserves the programmed max. power on the busbar and blocks for engagement of the heavy consumer, until sufficient predicted available power is present at the busbar.



Power reservation at the busbar before engagement of a heavy consumer (here 250 kW).

After achieving sufficient predicted available power, the heavy consumer is subsequently blocked until the programmed delay runs out.

The 'DELAY ACK. HC' may be necessary in order to allow the recently started generator set to take load and thus actually increase the available power at the busbar before engagement of the HC.

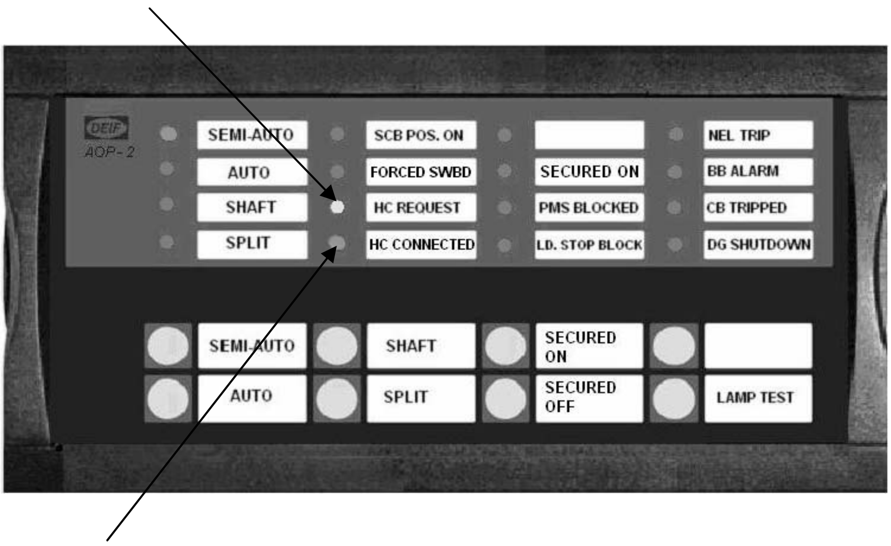
The heavy consumers (HC) are connected according to their priority. This means, if two or more heavy consumers request start acknowledgement at the same time, the HC with the highest priority is handled first, subsequently HCs with lower priority etc.

HC 1 is designated the highest priority. This means that HC 1 is handled before HC 2, if they are requested for start at the same time. If there are any preferential HCs, they must be connected to the hardware interface for HC 1 in order to ensure first priority handling.

The power management system carries out the following systematic sequence, when a heavy consumer is requested for start:

a) The programmed 'HC n MAX POWER' value is reserved at the busbar.
b) A PMS start command is transmitted to the next stand-by generator set, if the predicted available power is below the programmed 'LOAD START LIMIT'.
c) When sufficient available power is present at the busbar, the timer 'DELAY ACK. HC n' starts running.
d) The start acknowledge signal is transmitted to the HC in question, when the timer 'DELAY ACK. HC n' runs out and sufficient available power is still measured at the busbar.

A yellow 'HC REQUESTED' LED indicates a heavy consumer request signal at the AOP.



A green 'HC CONNECTED' LED indicates a connected heavy consumer.

The operator is able to change the maximum expected power consumption separately for two heavy consumers in each generator unit:

The power feedback from the heavy consumer
The PPU power management system is able to handle two types of power feedback:

- Binary feedback
- Analogue feedback

The two types of power feedback signals are handled the same way by the conditional connection of heavy consumers function.

Changing the power feedback type is done by the following set point in each generator unit:

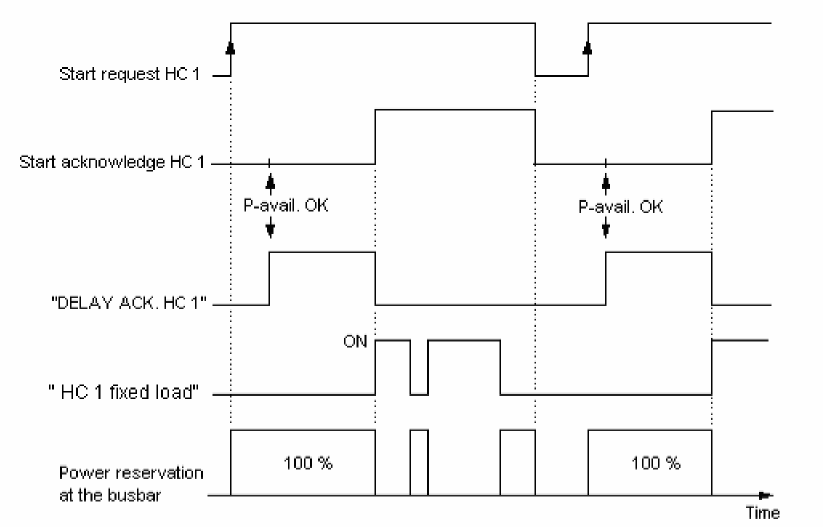
The nature of the HC
The power feedback type should be considered according to the nature of the heavy consumer:

- An HC with variations in load (**variable load** as a thruster) should always be assigned with an analogue power feedback.
- An HC with **fixed load** should be selected with a binary feedback.

Start of heavy consumers with fixed load
The conditional connection of heavy consumers with fixed load is controlled via the following hardware interface:

SIGNAL NAME	SIGNAL TYPE	LOCATION
• START REQ. HC 1	Binary input	Terminal no. 44
• START REQ. HC 2	Binary input	Terminal no. 45
• HC 1 CONNECTED	Binary input	Terminal no. 46
• HC 2 CONNECTED	Binary input	Terminal no. 47
• HC no.1 FIXED LOAD	Binary input	Terminal no. 48
• HC no.2 FIXED LOAD	Binary input	Terminal no. 49
• START ACK. HC 1	Relay output	Terminal no. 57/58
• START ACK. HC 2	Relay output	Terminal no. 59/60

Activating the corresponding start request binary input activates the HC engagement sequence. The PPM system transmits a start acknowledge signal when sufficient predicted available power is present at the busbar.



The engagement sequence for HCs with fixed load

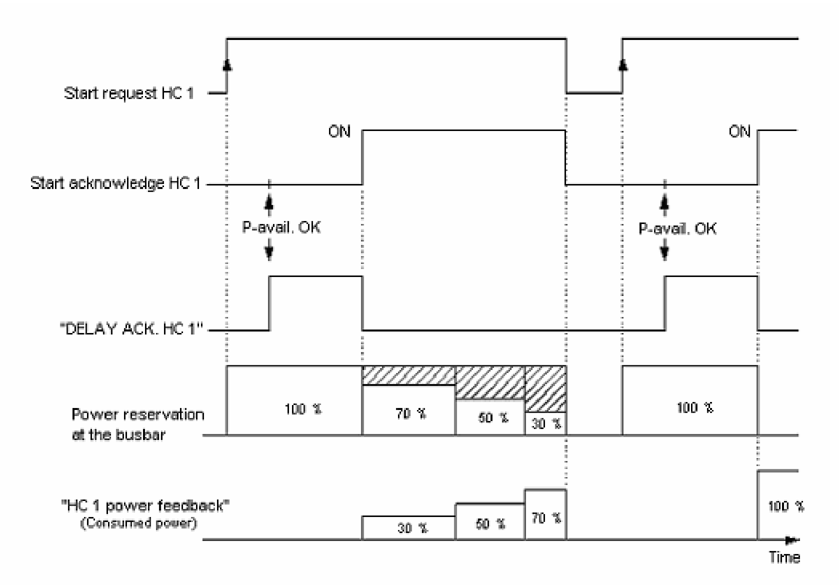
The power reservation by means of the power feedback input is enabled for as long as the **start request** signal is active. An OFF status (indicates that the HC is not operating) of the power feedback signal results in a 100% power reservation at the busbar. An ON status (indicates that the HC is operating) at the power feedback signal results in a 0% power reservation at the busbar.

Start of heavy consumers with variable load

The conditional connection of heavy consumers with variable load is controlled via the following hardware interface:

SIGNAL NAME	SIGNAL TYPE	LOCATION
• START REQ. HC 1	Binary input	Terminal no. 44
• START REQ. HC 2	Binary input	Terminal no. 45
• HC 1 CONNECTED	Binary input	Terminal no. 46
• HC 2 CONNECTED	Binary input	Terminal no. 47
• HC no. 1 VARIABLE LOAD • HC no. 2 VARIABLE LOAD	Analogue input Analogue input	Terminal no. 98(+)/99(-) Terminal no. 100(+)/101(-)
• START ACK. HC 1	Relay output	Terminal no. 57/58
• START ACK. HC 2	Relay output	Terminal no. 59/60

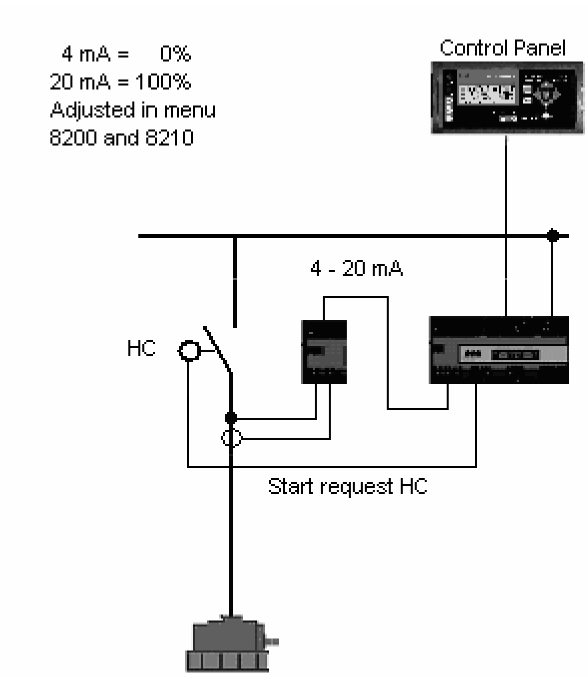
The HC engagement sequence will be activated by activating the corresponding start request input. The power reservation ends after disappearing of the start request signal (CC→OC).



The engagement sequence for HCs with variable load.

Power feedback
The power feedback for the heavy consumer is intended for a power transducer with a 4-20mA output corresponding to 0-100% load. It is only the 100% load which is adjustable. This is done in menu 8200 for HC1 and 8210 for HC2.

If the heavy consumer is on 400 kW, then the power transducer has to be calibrated to 0-400 kW = 4-20mA, and the setting in menu 8200 also has to be set for 400 kW.



The power management unit transmits a start acknowledge signal when sufficient available power for safe operation of the HC is present at the bus bar. The acknowledge signal has an ON duration of 2 s.

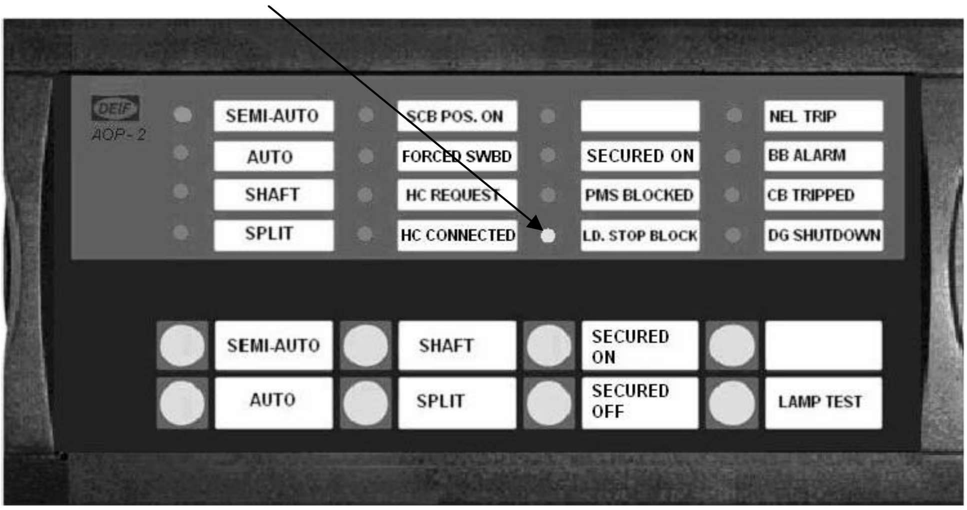
In order to prevent overload at the busbar during operation of heavy consumers, the actual power consumed by the HC (represented by the power feedback) is taken into consideration.

Based on this knowledge, the reserved power at the busbar for this HC is reduced (from maximum power) with the actually consumed power. This calculation is done continuously in order to optimise the reserved power at the busbar.

But it is also possible to block the load dependent stop as long as a heavy consumer is connected to the busbar (set point 8035).

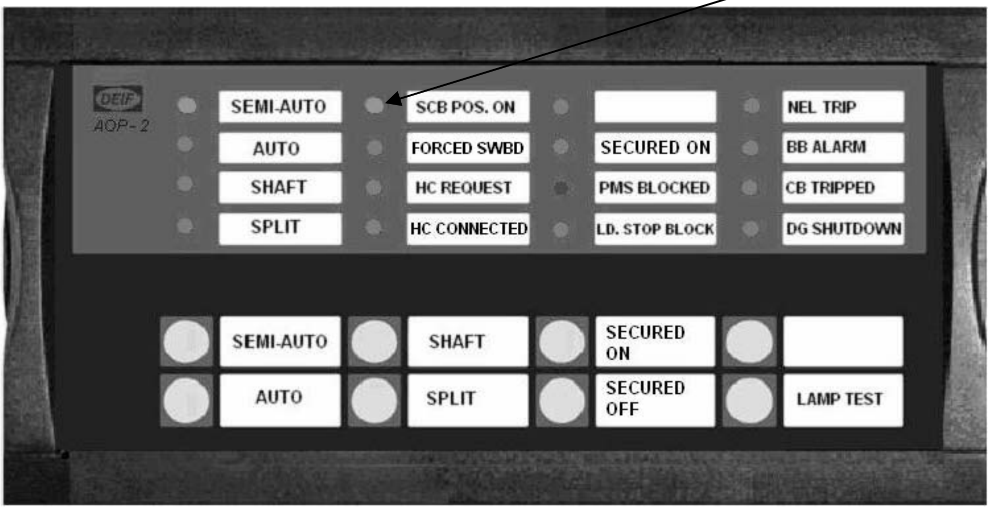
The load dependent stop blocking function is automatically ignored, if there is **not** a heavy consumer (HC) connected to the busbar. The load dependent stop blocking function via the binary input will be active as long as the input is set.

A load dependent **stop blocking** is indicated on the additional operator panel by a yellow LED.



Supervision of the shore connection

The position of the shore connection breaker is indicated at the AOP by a green 'SCB POS. ON' LED. (Not used with system 2 (shore)).



The shore connection has to be connected manually from the switchboard.

Switching from diesel generator supply to shore supply:

1. Select the SEMI-AUTO plant mode.
2. Decrease the load on the busbar until one diesel generator can handle the load.
3. Use the display panel to disconnect the diesel generators from the busbar. (It will not be possible to disconnect the last feeding generator breaker).
4. Select SWBD control for all diesel generators.
5. Disconnect the last feeding generator breaker manually (switchboard) from the busbar (creating blackout).
6. Connect the shore connection breaker.
7. Select PMS control for all diesel generators.
8. Stop the running diesel generators from the display unit.

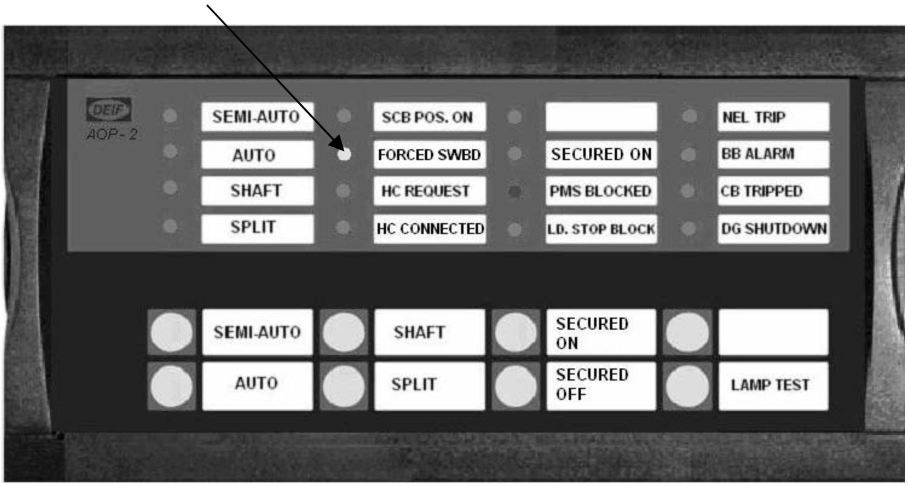
Switching from shore supply to diesel generator supply:

1. Select the SEMI-AUTO plant mode.
2. Start one diesel generator.
3. Disconnect the shore connection breaker (the diesel generator will automatically close the breaker due to the blackout start sequence).

If the shore connection breaker is in position ON, the power management functions are blocked. This is indicated by a red "PMS BLOCKED" LED at the AOP-2.

Forced switchboard control

The PPU power management system can be forced to switchboard control by activating the "FORCED SWBD" input. This is indicated by a yellow 'FORCED SWBD' LED.



If the "FORCED SWBD" input is set, the entire system will be forced to be in switchboard control. This can for example be used in connection with a bus coupling switch.

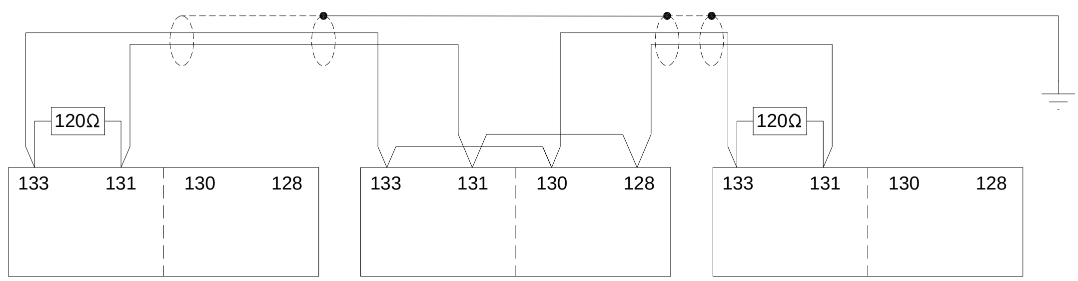
10. Internal communication

The CAN is for internal use only. There is no possibility of connecting this to other systems. If external communication is needed, a second communication board (one of the options H) must be selected as well.

Term.	Function	Description
126	Not used	CAN bus
127	Not used	
128	Can-L	
129	Cable screen	
130	Can-H	
131	Can-L	
132	Cable screen	
133	Can-H	

Terminals 128 and 131 are internally connected.
Terminals 129 and 132 are internally connected.
Terminals 130 and 133 are internally connected.

CAN bus wirings



Terminals 129 and 132 are intended for the cable screen, not for GND.

11. External communication

The external communication can be done to another system like external alarm and monitoring system or engine controller.

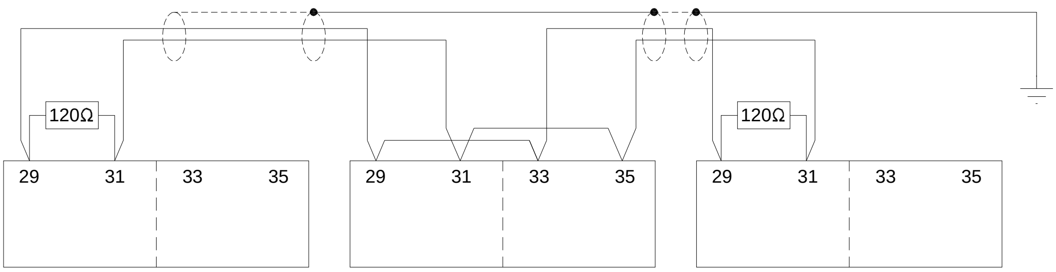
The description here is only for a quick reference. For the full description of the possibilities and protocols, please refer to the option description

Modbus RTU (option H2)

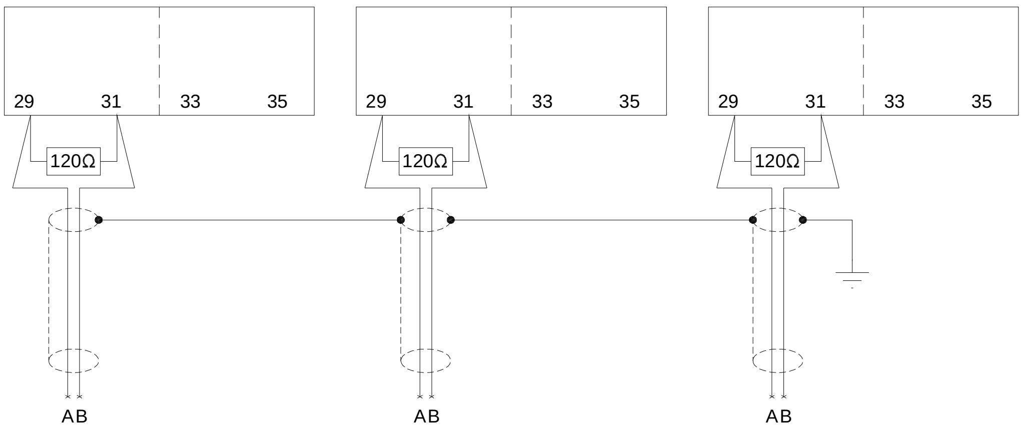
Term. Slot #2	Function	Description
29	DATA + (A)	Modbus RTU, RS485
30	Cable screen	
31	DATA - (B)	
32	Not used	
33	DATA + (A)	
34	Not used	
35	DATA - (B)	
36	Not used	

Modbus wirings

Multi drop connection



Point to point connection



DEIF A/S reserves the right to change any of the above