-power in control

DESIGNER'S REFERENCE HANDBOOK



Generator Protection Unit, GPU-3 Hydro

- Functional description
- General product information
- Additional functions
- PID controller
- Synchronisation

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1. General information

2. General product information

3. Functional descriptions

4. Additional functions

5. Protections

6. PID controller (option G2)

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1. General information

1.1 Warnings, legal information and safety

1.1.1 Warnings and notes

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

Warnings

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

Notes

Notes provide general information, which will be helpful for the reader to bear in mind.

1.1.2 Legal information and disclaimer

DEIF takes no responsibility for installation or operation of the generator set. If there is any doubt about how to install or operate the engine/generator controlled by the Multi-line 2 unit, the company responsible for the installation or the operation of the set must be contacted.

The Multi-line 2 unit is not to be opened by unauthorised personnel. If opened anyway, the warranty will be lost.

Disclaimer

DEIF A/S reserves the right to change any of the contents of this document without prior notice.

1.1.3 Safety issues

Installing and operating the Multi-line 2 unit may imply 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.

1.1.4 Electrostatic discharge awareness

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

1.1.5 Factory settings

The Multi-line 2 unit is delivered from factory with certain factory settings. These are based on average values and are not necessarily the correct settings for matching the engine/generator set in question. Precautions must be taken to check the settings before running the engine/generator set.

1.2 About the designer's reference handbook

1.2.1 General purpose

This Designer's Reference Handbook mainly includes functional descriptions, presentation of display unit and menu structure, information about the PID controller, the procedure for parameter setup and reference to parameter lists.

The general purpose of this document is to provide useful overall information about the functionality of the unit and its applications. This document also offers the user the information he needs in order to successfully set up the parameters needed in his specific application.

⚠ **Please make sure to read this document before starting to work with the Multi-line 2 unit and the genset to be controlled. Failure to do this could result in human injury or damage to the equipment.**

1.2.2 Intended users

This Designer's Reference Handbook is mainly intended for the panel builder designer in charge. On the basis of this document, the panel builder designer will give the electrician the information he needs in order to install the Multi-line 2 unit, e.g. detailed electrical drawings. In some cases, the electrician may use these installation instructions himself.

1.2.3 Contents and 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.

2. General product information

2.1 General product information

2.1.1 About

This chapter will deal with the unit in general and its place in the DEIF product range.

2.1.2 Introduction

The GPU-3 Hydro is part of the DEIF Multi-line 2 product family. Multi-line 2 is a complete range of multi-function generator protection and control products integrating all the functions you need into one compact and attractive solution.

2.1.3 Type of product

The Generator Protection Unit is a micro-processor based control unit containing all necessary functions for protection and control of a generator.

It contains all necessary 3-phase measuring circuits, and all values and alarms are presented on the LCD display

2.1.4 Options

The Multi-line 2 product range consists of different basic versions which can be supplemented with the flexible options needed to provide the optimum solution. The options cover e.g. various protections for generator, mains, voltage control, various outputs, serial communication, etc.

A complete list of available options is included in the data sheet, document no. 4921240353. Please see www.deif.com.

2.1.5 PC utility software warning

It is possible to remote-control the genset from the PC utility software, by use of a modem or TCP/IP. To avoid personal injury, make sure that it is safe to remote-control the genset.

3. Functional descriptions

3.1 Functional descriptions

3.1.1 About

This chapter includes functional descriptions of standard functions as well as illustrations of the relevant application types. Single-line diagrams will be used in order to simplify the information.

3.1.2 Standard functions

The standard functions are listed in the following paragraphs.

Generator protection (ANSI)
- 2 x reverse power (32)
- 5 x overload (32)
- 6 x overcurrent (50/51)
- 2 x overvoltage (59)
- 3 x undervoltage (27)
- 3 x over-/underfrequency (81)
- Voltage dependent overcurrent (51 V)
- Current/voltage unbalance (60)
- Loss of excitation/overexcitation (40/32 RV)

Busbar protection (ANSI)
- 3 x overvoltage (59)
- 4 x undervoltage (27)
- 3 x overfrequency (81)
- 4 x underfrequency (81)
- Voltage unbalance (60)
- 3 x NEL groups

Mains protection (ANSI)
- Vector jump (78)
- df/dt (ROCOF) (81R)
- Time-dependent undervoltage (27T)
- Reactive power-dependent undervoltage (27Q)

M-Logic (Micro PLC)
- Simple logic configuration tool
- Selectable input/output events

Display
- Status texts
- Info messages
- Alarm indication
- Prepared for remote mounting
- Prepared for additional remote displays

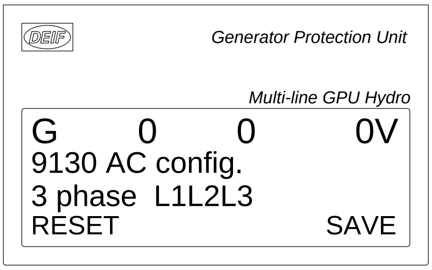
General
- USB interface to PC
- Free PC utility software
- Programmable parameters, timers and alarms
- User configurable texts

3.1.3 Measurement systems

The GPU-3 Hydro is designed for measurement of voltages between 100 and 690V AC. For further reference, the AC wiring diagrams are shown in the Installation Instructions. In menu 9130, the measurement principle can be changed between three-phase, single phase and split phase.

The settings can be changed by using the display. Press the JUMP push-button and go to the menu 9130 or use the USW.

The menu for adjusting the measurement principle looks like this:



Use the or push-button to choose between 1-phase, 2-phase or 3-phase. Press until SAVE is underscored, and then press to save the new setting.

Configure the GPU-3 Hydro to match the correct measuring system. When in doubt, contact the switchboard manufacturer for information about the required adjustment.

Three-phase

When the GPU-3 Hydro is delivered from the factory, the three-phase system is selected. When this principle is used, all three phases must be connected to the GPU-3 Hydro.

The following adjustments must be made in order to make the system ready for the three-phase measuring (example 400/230V AC):

Setting/Adjustment		Description	Adjust to value
6004	G nom. voltage	Phase-phase voltage of the generator	400V AC
6041	G transformer	Primary voltage of the voltage transformer (if installed)	U_{NOM}
6042	G transformer	Secondary voltage of the voltage transformer (if installed)	U_{NOM}
6051	BB transformer	Primary voltage of the BB voltage transformer (if installed)	U_{NOM}
6052	BB transformer	Secondary voltage of the BB voltage transformer (if installed)	U_{NOM}
6053	BB nom. voltage	Phase-phase voltage of the busbar	U_{NOM}

Split phase

This is a special application where two phases and neutral are connected to the GPU-3 Hydro. The GPU-3 Hydro shows phases L1 and L3 in the display. The phase angle between L1 and L3 is 180 degrees. Split phase is possible between L1-L2 or L1-L3.

The following adjustments must be made in order to make the system ready for the split phase measuring (example 240/120V AC):

Setting/Adjustment		Description	Adjust to value
6004	G nom. voltage	Phase-phase voltage of the generator	120
6041	G transformer	Primary voltage of the voltage transformer (if installed)	U_{NOM}
6042	G transformer	Secondary voltage of the voltage transformer (if installed)	U_{NOM}
6051	BB transformer	Primary voltage of the voltage transformer (if installed)	U_{NOM}
6052	BB transformer	Secondary voltage of the voltage transformer (if installed)	U_{NOM}
6053	BB nom. voltage	Phase-phase voltage of the busbar	U_{NOM}

The measurement U_{L3L1} shows 240V AC. The voltage alarm setpoints refer to the nominal voltage 120V AC, and U_{L3L1} does not activate any alarm.

Single phase
The single phase system consists of one phase and the neutral.

The following adjustments must be made in order to make the system ready for the single phase measuring (example 230V AC):

Setting/Adjustment		Description	Adjust to value
6004	G nom. voltage	Phase-phase voltage of the generator	230
6041	G transformer	Primary voltage of the voltage transformer (if installed)	$U_{NOM} \times \sqrt{3}$
6042	G transformer	Secondary voltage of the voltage transformer (if installed)	$U_{NOM} \times \sqrt{3}$
6051	BB transformer	Primary voltage of the voltage transformer (if installed)	$U_{NOM} \times \sqrt{3}$
6052	BB transformer	Secondary voltage of the voltage transformer (if installed)	$U_{NOM} \times \sqrt{3}$
6053	BB nom. voltage	Phase-phase voltage of the busbar	$U_{NOM} \times \sqrt{3}$

The voltage alarms refer to U_{NOM} (230V AC).

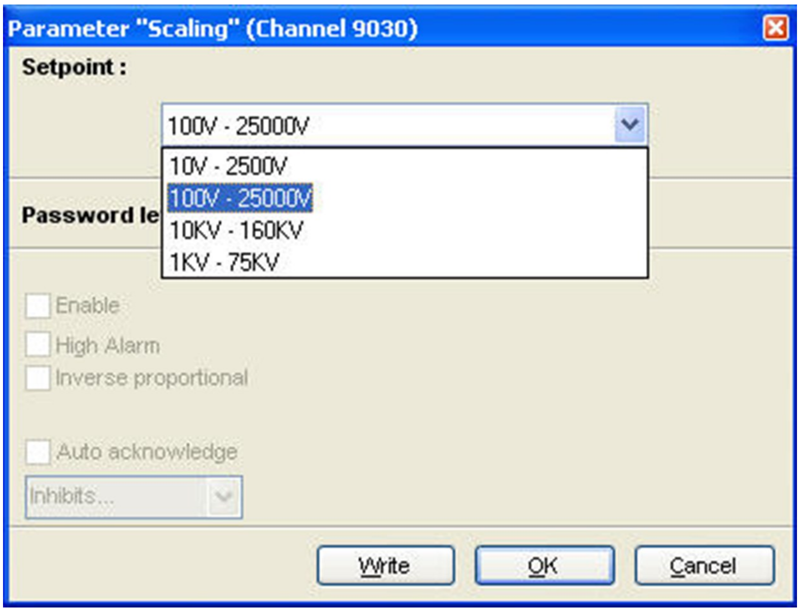
3.1.4 Scaling

Default voltage scaling for the GPU-3 Hydro is set to 100 V-25000 V. To be able to handle applications above 25000 V and below 100 V, it is necessary to adjust the input range so it matches the actual value of the primary voltage transformer. This makes it possible for the GPU-3 Hydro to support a wide range of voltage and power values.

Setup of the scaling can be done from the display by using the jump function or by using the USW.

When changing the voltage scaling in menu 9030, the unit will reset. If it is changed via the USW, it is necessary to read the parameter again.

Scaling of nominal voltage and voltage read-out is done in menu 9030.



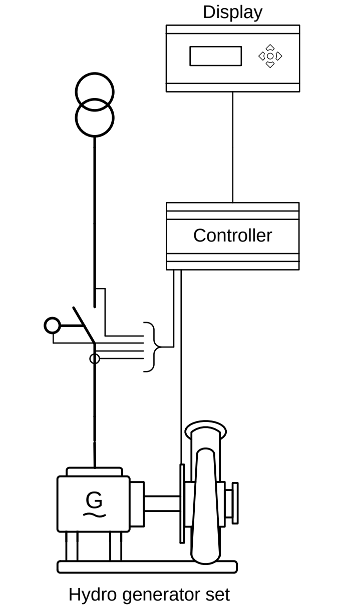
Changing the voltage scaling will also influence the nominal power scaling:

Scaling parameter 9030	Nom. settings 1 to 4 (power)	Nom. settings 1 to 4 (voltage)	Menu: 6041, 6051 and 6053
10 V-2500 V	1.0-900.0 kW	10.0 V-2500.0 V	10.0 V-2500.0 V
100 V-25000 V	10-20000 kW	100 V-25000 V	100 V-25000 V
1 kV-75 kV	0.10-90.00 MW	1.00 kV-75.00 kV	1.00 kV-75.00 kV
10 kV-160 kV	1.0-900.0 MW	10.0 kV-160.0 kV	10.0 kV-160.0 kV

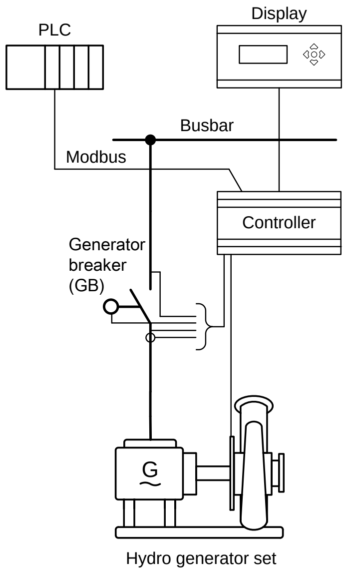
3.2 Single-line diagrams

The GPU-3 Hydro can be used for numerous applications. A few examples are shown below, but due to the flexibility of the product, it is not possible to show all applications. The flexibility is one of the great advantages of this controller.

Generator/mains protection



PLC-controlled system



The GPU-3 Hydro can be used in simple or complex applications. The above shows very simple applications only, but due to the flexibility, the GPU-3 Hydro can be used in all types of applications.

3.3 Password and parameter access

3.3.1 Password

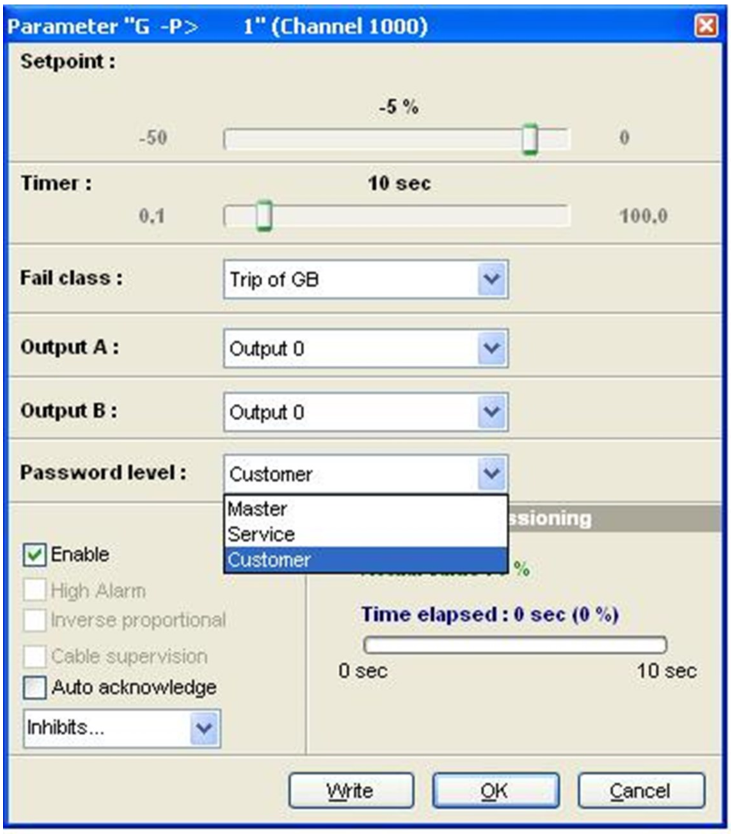
The unit includes three password levels. All levels can be adjusted in the PC software.

Available password levels:

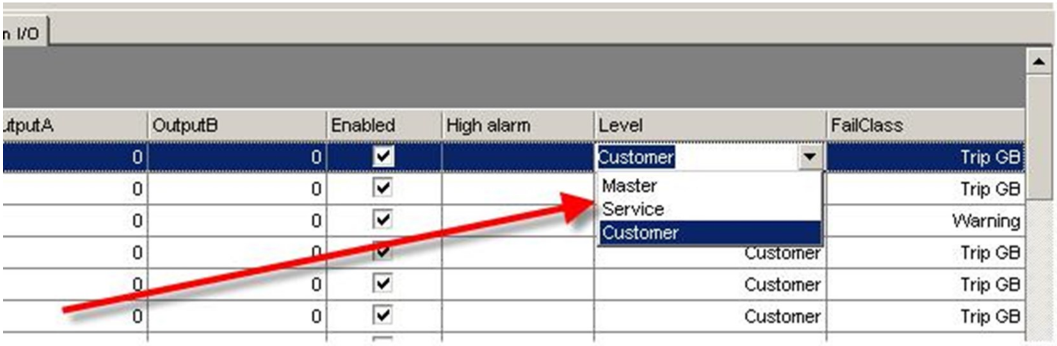
Password level	Factory setting	Access		
		Customer	**Service**	**Master**
Customer	2000	X		
Service	2001	X	X	
Master	2002	X	X	X

A parameter cannot be entered with a password that is ranking too low. But the settings can be displayed without password entry.

Each parameter can be protected by a specific password level. To do so, the PC utility software must be used. Enter the parameter to be configured and select the correct password level.



The password level can also be changed from the parameter view in the column "Level".



3.3.2 Parameter access

To gain access to adjust the parameters, the password level must be entered:

If the password level is not entered, it is not possible to enter the parameters.

The customer password can be changed in jump menu 9116. The service password can be changed in jump menu 9117. The master password can be changed in jump menu 9118.

The factory passwords must be changed if the operator of the genset is not allowed to change the parameters.

It is not possible to change the password at a higher level than the password entered.

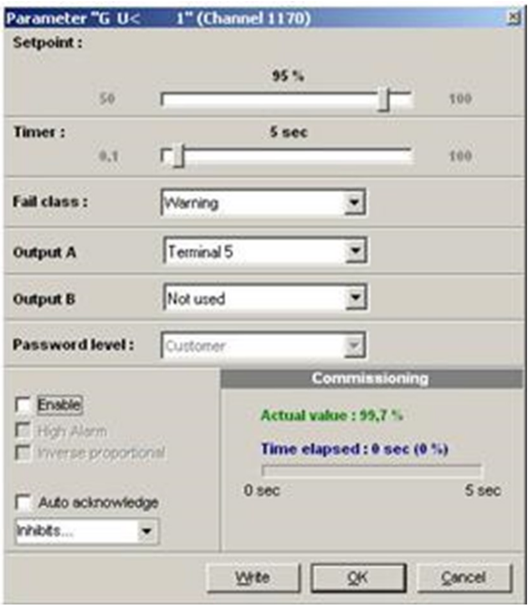
4. Additional functions

4.1 Additional functions

The alarm function of the GPU-3 Hydro includes the possibility to display the alarm texts, activate relays or display alarm texts combined with relay outputs.

Setup
The alarms must typically be set up with setpoint, timer, relay outputs and enabling. The adjustable setpoints of the individual alarms vary in range, e.g. the minimum and maximum settings.

USW 3 setup:



DU-2 setup:

G 0 0 0V
1170 G U< 1
Relay 5
SP DEL OA OB ENA FC

SP = setpoint. DEL= timer. OA = output A. OB = output B. ENA = enable. FC = fail class.

Alarm display
All enabled alarms will be shown in the display, unless the output A as well as the output B are adjusted to a “limit” relay.

If output A and output B are adjusted to a limit relay, then the alarm message will not appear but the limit relay will activate at a given condition.

Definitions

There are three states for an enabled alarm.

1. Alarm is not present: The display does not show any alarm.
   The alarm LED is dark.

2. Unacknowledged state: The alarm has exceeded its setpoint and delay, and the alarm message is displayed. The GPU-3 Hydro is in the alarm state, and it can only leave the alarm state if the cause of the alarm disappears and the alarm message is acknowledged at the same time. The alarm LED is flashing.

3. Acknowledged state: The alarm will be in an acknowledged state if the alarm situation is present and the alarm has been acknowledged. The alarm LED is lit with fixed light. Any new alarm will make the LED flash.

Alarm acknowledge

The alarms can be acknowledged in two ways, either by means of the binary input “Alarm acknowledge” or the push-buttons on the display.

Binary acknowledge input

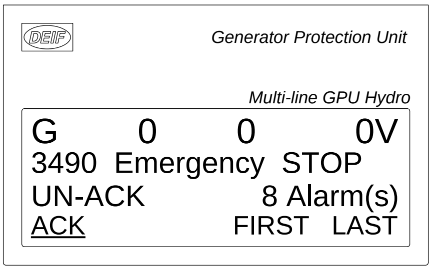
The alarm acknowledge input acknowledges all present alarms, and the alarm LED will change from flashing light to fixed light (alarms still present) or no light (no alarms present).

It is not possible to acknowledge individual alarms with the binary alarm acknowledge input. All alarms will be acknowledged when the input is activated.

Display acknowledge (push-buttons)

The display can be used for alarm acknowledgement when the alarm info window is entered. Pressing the “INFO” button will open this window.

The alarm information window displays one alarm at a time together with the alarm state (alarm acknowledged or not). If the alarm is unacknowledged, move the cursor to “ACK” and press select to acknowledge it.



Use the and push-buttons to scroll through the alarm list. The alarm list contains all present alarms.

Relay outputs

In addition to the display message of the alarms, each alarm can also activate one or two relays if this is required.

Adjust output A (OA) and/or output B (OB) to the desired relay(s).

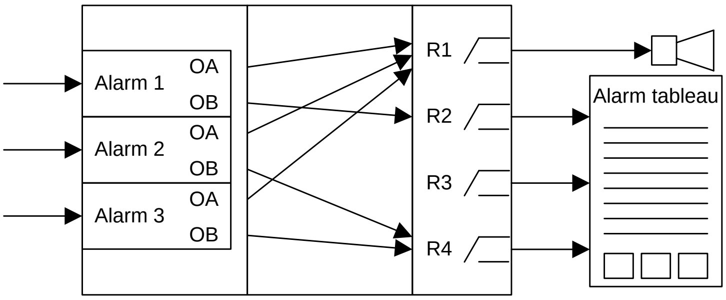
In the example in the drawing below, three alarms are configured and relays 1-4 are available as alarm relays.

When alarm 1 appears, output A activates relay 1 (R1) which activates an alarm horn on the diagram. Output B of alarm 1 activates relay 2 (R2). In the diagram, R2 is connected to the alarm panel.

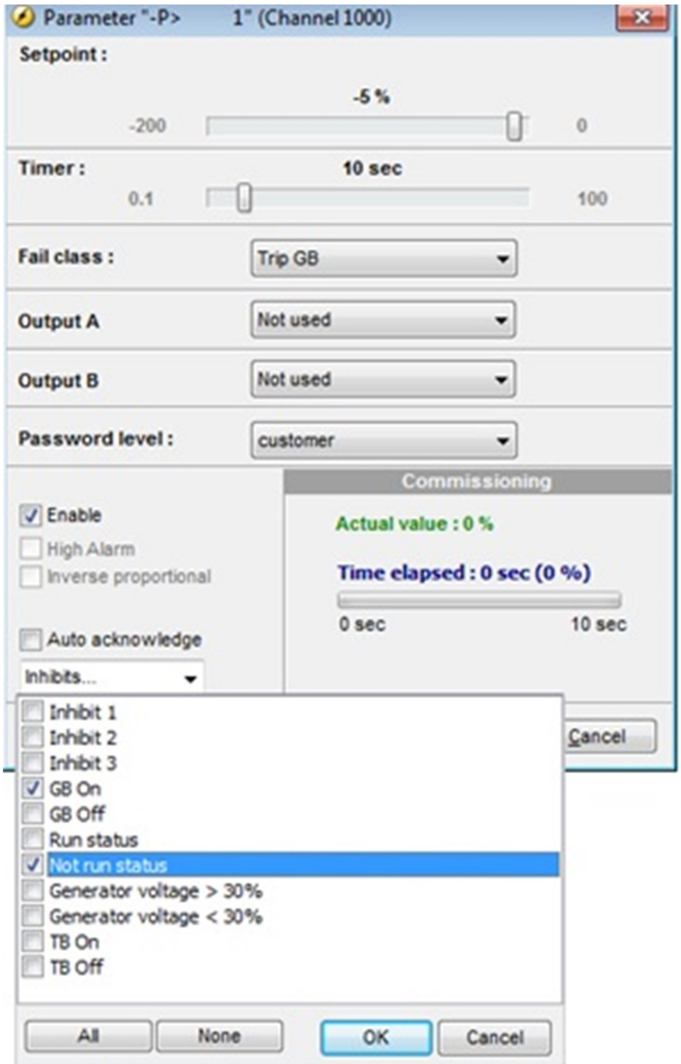
Alarm 2 activates R1 and R4.
Alarm 3 activates R1 and R4.

Several alarms can activate the same relay.

Each alarm can activate none, one or two relays. (None means that only a display message is given).



In order to select when the alarms are to be active, a configurable **inhibit** setting for each alarm has been made. The inhibit functionality is only available via the PC utility software. For each 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.

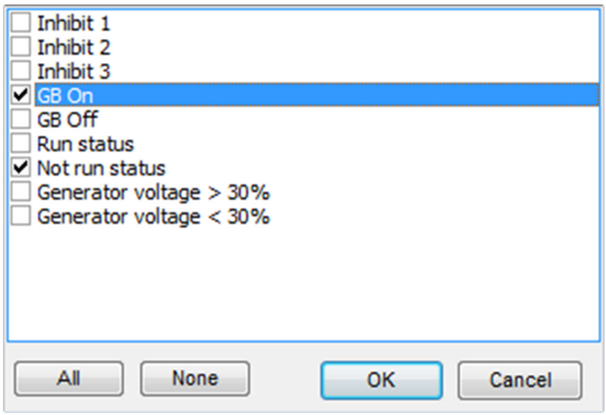

Parameter "-P> 1" (Channel 1000)
Setpoint :
-5 %
-200
0
Timer :
10 sec
0.1
100
Fail class :
Trip GB
Output A
Not used
Output B
Not used
Password level :
customer
Commissioning
Enable
High Alarm
Inverse proportional
Actual value : 0 %
Time elapsed : 0 sec (0 %)
0 sec
10 sec
Auto acknowledge
Inhibits...
Inhibit 1
Inhibit 2
Inhibit 3
GB On
GB Off
Run status
Not run status
Generator voltage > 30%
Generator voltage < 30%
TB On
TB Off
Cancel
All
None
OK
Cancel

Selections for alarm inhibit:

Function	Description
Inhibit 1	Input function (alarm inhibit 1) or M-Logic output
Inhibit 2	M-Logic outputs: Conditions are programmed in M-Logic
Inhibit 3	
GB ON	The generator breaker is closed
GB OFF	The generator breaker is open
Run status	Running detected and the timer in menu 6160 expired
Not run status	Running not detected or the timer in menu 6160 not expired
Generator voltage > 30%	Generator voltage is above 30% of nominal
Generator voltage < 30%	Generator voltage is below 30% of nominal

The timer in 6160 is not used if digital running feedback is used

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



In this example, inhibit is set to **Not run status** and **GB On**. Here, the alarm will be active when the generator has started. When the generator has been synchronised to the busbar, the alarm will be disabled again

The inhibit LED on the base unit will activate when one of the inhibit functions is active.

Function inputs such as running feedback, remote start or access lock are never inhibited. Only alarm inputs can be inhibited.

4.1.1 Alarm jump

This function is used to select the behaviour of the display view when an alarm is activated.

Setup is done in menu 6900 Alarm jump:

Enable	Action when an alarm is activated
ON (default)	The display view will change to the alarm info list
OFF	The display view will stay at the present view

4.1.2 Digital input function

The unit has a number of digital inputs. These inputs can be configured as inputs with dedicated logic functions or they can be configured as alarm inputs.

Input functions

The table below illustrates all the input functions available in the GPU-3 Hydro and shows in which operation mode the described function will be active.

X = function can be activated.

	Input function	Remote	Local	Man	SWBD	Input type	Note
1	Access lock	X	X	X	X	Constant	
2	Start sync./control	X				Constant	Option G2 or M4
3	Deload	X				Constant	Option G2
4	Local mode	X				Pulse	Option G2 or M4
5	Remote mode		X			Pulse	
6	SWBD control	X	X	X		Constant	Option G2 or M4
7	Manual mode	X	X			Constant	Option G2
8	Alarm inhibit 1	X	X	X	X	Constant	
9	Remote GB ON	X				Pulse	Option G2
10	Remote GB OFF	X				Pulse	
11	Remote alarm ack.	X	X	X	X	Pulse	
12	Ext. communication control	X				Constant	Option H2 or H3
13	Reset analogue GOV/AVR outputs	X	X	X		Pulse	
14	Manual GOV up			X		Constant	Option G2
15	Manual GOV down			X		Constant	
16	Manual AVR up			X		Constant	Option G2
17	Manual AVR down			X		Constant	
18	Island mode	X	X			Constant	Option G2
19	Enable GB black close	X	X	X		Constant	Option G2
20	Enable sep. sync.	X	X	X		Constant	
21	GB spring loaded	X	X	X		Constant	
22	Digital running feedback	X	X	X	X	Constant	Option M4
23	Shutdown override	X	X	X	X	Constant	
24	Low speed	X	X			Constant	
25	Battery test	X	X			Constant	
26	Start enable	X	X	X		Constant	
27	Remove starter	X	X	X		Constant	
28	Remote start	X	X			Pulse	
29	Remote stop	X	X			Pulse	
30	GB close inhibit	X	X	X		Constant	Option G2

Functional description

1. Access lock
Activating the access lock input deactivates the control display push-buttons. It will only be possible to view measurements, alarms and the log.

2. Start sync./control

The input starts the regulation and the control of the GOV(/AVR) is performed by the GPU-3 Hydro. If the CB is open, then synchronising will start and if the CB is closed, then the selected method of regulation will depend on the mode input selection.

When the GB is closed and the input is OFF, the GPU is in manual control mode and the display shows “MANUAL”.

To activate this command from M-Logic or external communication (e.g. Modbus), the M-Logic command “Start sync./ctrl enable” has to be activated. Alternatively, you can use the functions “Remote GB ON” and “Remote GB OFF”.

3. Deload
The input starts the deload function of the GPU-3 Hydro. This will either be “Open breaker”, “Deload and open breaker” or “Prevent synchronising”.

This function only works together with “Start sync./control”.

4. Local
Changes the present running mode to local.

5. Remote
Changes the present running mode to remote.

6. SWBD control
Activates switchboard control, i.e. all controls and commands will stop. Protections are still active.

7. Manual
Changes the present running mode to manual.

8. Alarm inhibit 1
Specific alarms are inhibited to prevent the alarms from occurring.

Essential protections might also be inhibited, if inhibit is used.

9. Remote GB ON
The generator breaker ON sequence will be initiated and the breaker will synchronise if the busbar voltage is present, or close without synchronising if the busbar voltage is not present.

10. Remote GB OFF
The generator breaker OFF sequence will be initiated. In fixed frequency mode, the generator breaker will open instantly. In any other mode, the generator load will be deloaded to the breaker open limit followed by a breaker open command.

11. Remote alarm acknowledge
Acknowledges all present alarms, and the alarm LED on the display stops flashing.

12. Ext. communication control
When the input is activated, the GPU-3 Hydro is controlled from Modbus or Profibus only.

13. Reset analogue GOV/AVR outputs

The analogue +/-20mA controller outputs will be reset to 0mA.

All analogue controller outputs are reset. That is the governor output and the AVR output if option D1 is selected.

If an offset has been adjusted in the control setup, then the reset position will be the specific adjustment.

14. Manual GOV up
If manual mode is selected, then the governor output will be increased.

15. Manual GOV down
If manual mode is selected, then the governor output will be decreased.

16. Manual AVR up
If manual mode is selected, then the AVR output will be increased.

17. Manual AVR down
If manual mode is selected, then the AVR output will be decreased.

The manual governor and AVR increase and decrease inputs can only be used in manual mode.

18. Island mode
This input deactivates the busbar measurements during breaker operations. This makes it possible to close the breaker from the GPU-3 Hydro even though the generator and busbar are not synchronised.

The GPU-3 Hydro will issue the close breaker signal even though the generator and busbar are NOT synchronised. If this function is used, additional breakers must be installed between the generator and the point from where the busbar measurements are taken for the GPU-3 Hydro. Otherwise the generator will close its circuit breaker without synchronism with subsequent damage, injury or death!

Serious personal injury, death and damaged equipment could be the result of using this input without proper safety precautions/testing prior to use. Take precautions that a high degree of safety is implemented in the application before using this function.

The function of the application must be checked and tested carefully during the commissioning when the island mode input is used. This is to ensure that no false breaker closings occur.

19. Enable GB black close
When the input is activated, the unit is allowed to close the generator on a dead busbar, providing that the frequency and voltage are inside the limits set up in menu 2110.

20. Enable separate sync.
Activating this input will split the breaker close and breaker synchronisation functions into two different relays. The breaker close function will remain on the relays dedicated for breaker control. The synchronisation function will be moved to a configurable relay dependent on the options configuration.

21. GB spring loaded
The unit will not send a close signal before this feedback is present.

22. Running feedback
The input is used as a running indication of the engine. When the input is activated, the start relay is deactivated.

23. Shutdown override
This input deactivates all protections except the overspeed protection and the emergency stop input. The number of start attempts is 7 by default, but it can be configured in menu 6201. Also a special cool down timer is used in the stop sequence after an activation of this input.

The genset will not shut down in case of serious alarms that would shut down the genset under normal operation.

24. Low speed
Disables the regulators and keeps the genset running at a low RPM.

The governor must be prepared for this function.

25. Battery test
Activates the starter without starting the genset. If the battery is weak, the test will cause the battery voltage to drop more than acceptable, and an alarm will occur.

26. Start enable
The input must be activated to be able to start the engine.

When the genset is started, the input can be removed.

27. Remove starter
The start sequence is deactivated. This means the start relay deactivates, and the starter motor will disengage.

28. Remote start
This input initiates the start sequence of the genset when remote mode is selected.

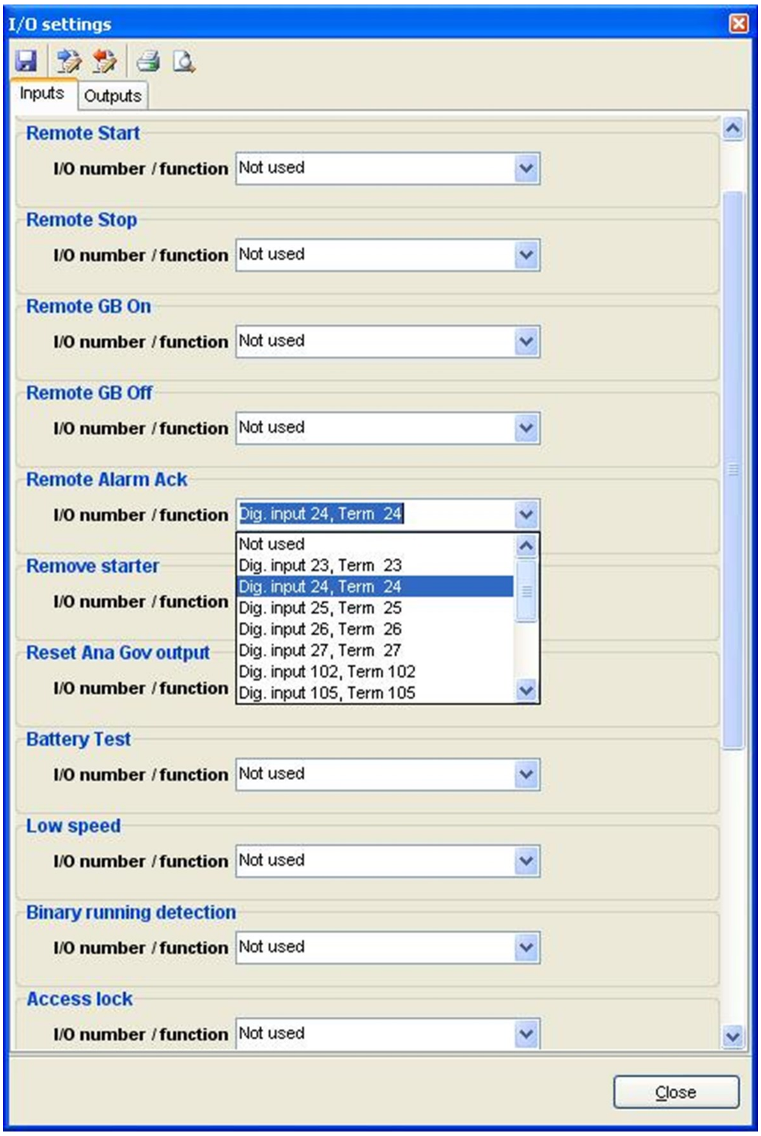
29. Remote stop
This input initiates the stop sequence of the genset when remote mode is selected. The genset will stop without cooling down.

30. GB close inhibit
When this input is activated, the GB ON sequence will not be initiated.

Configuration
The digital inputs are configured via the PC utility software.

Select the input icon in the horizontal toolbar.

The desired input number can now be selected for the individual input function via the roll-down panel.



The event logging of data is divided into 3 different groups:

- Event log containing 150 loggings
- Alarm log containing 30 loggings

- Battery test log containing 52 loggings

The logs can be viewed in the display or in the PC utility software. When the individual logs are full, each new event will overwrite the oldest event following the “first in – first out” principle.

Display

In the display, it looks like this when the “LOG” push-button is pressed:

```
G   400   400   400V
LOG Setup
Event log
Event  Alarm  Batt.
```

Now it is possible to select one of the 3 logs.

If “Event” is selected, the log could look like this:

```
G   400   400   400V
4170 Fuel level
06-24        15:24:10.3
INFO         FIRST  LAST
```

The specific alarm or event is shown in the second line. In the example above the fuel level alarm has occurred. The third line shows the time stamp.

If the cursor is moved to “INFO”, the actual value can be read when pressing “SEL”:

```
G   400   400   400V
4170 Fuel level
VALUE              8%
INFO         FIRST  LAST
```

The first event in the list will be displayed, if the cursor is placed below “FIRST” and “SEL” is pressed.

The last event in the list will be displayed, if the cursor is placed below “LAST” and “SEL” is pressed.

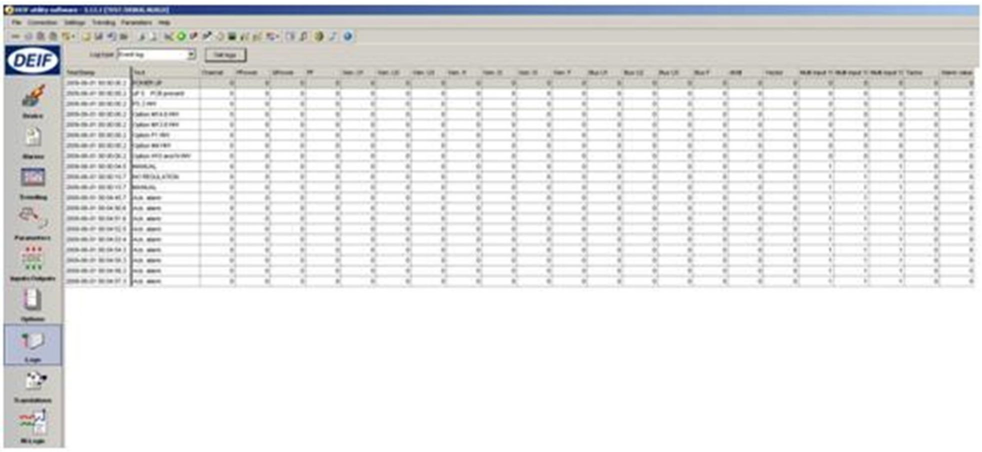
The and push-buttons are used to navigate in the list.

PC utility software

Using the PC utility software, the entire log stack of the last 150 events can be retrieved by activating the log button on the horizontal toolbar.

The alarms and events are displayed as indicated below. The actual alarms are displayed in the text column together with selected measurements.

In the right side column, additional data is indicated. This is specific data for the most important measurements. The data is logged for each specific event and is used for troubleshooting after each alarm.



The entire log can be saved in Excel format and used in that particular programme.

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

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

Engine running

Fail class	Action				
	Alarm horn relay	Alarm display	Trip of GB	Coolingdown genset	Stop genset
1 Block	X	X			
2 Warning	X	X			
3 Trip of GB	X	X	X		
4 Trip and stop	X	X	X	X	X
5 Shutdown	X	X	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 horn relay will activate
- The alarm will be displayed in the alarm info screen
- The generator breaker will open instantly
- The genset is stopped instantly
- The genset cannot be started from the unit (see next table)

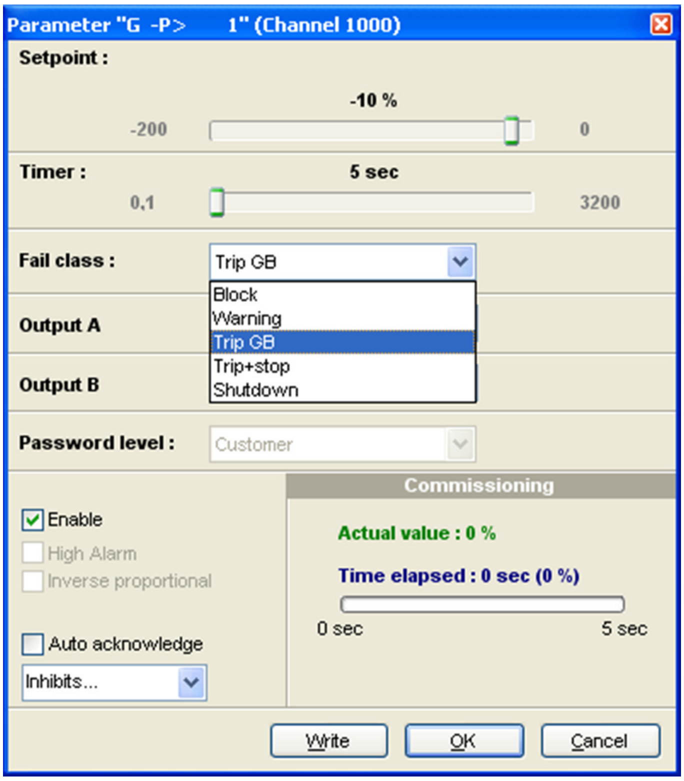
Engine stopped

Fail class	Action	
	Block engine start (option M4)	**Block GB sequence**
1 Block	X	
2 Warning		
3 Trip GB	X	X
4 Trip and stop	X	X
5 Shutdown	X	X

In addition to the actions defined by the fail classes, it is possible to activate one or two relay outputs, if additional relays are available in the unit.

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.



All configurable relays can be chosen to be a horn output. This means that the relay can be connected to an alarm annunciator, e.g. a horn. Every time a new alarm occurs, the horn output will activate.

The horn output will activate on all alarms. The output remains activated until:

- The alarm is acknowledged
- The horn relay timer runs out (automatic reset function)

When a relay is used as a horn relay, it cannot be used for other purposes.

The horn output will not activate on limit switch functions.

Automatic reset
The horn relay function has an automatic reset function. When the timer (menu 6130) differs from 0 seconds, the horn relay output resets itself when the delay has expired. This is also the situation when the alarm is STILL present.

The horn output resets when the alarm is still present. This is the function of the “Automatic reset”.

Manual reset
If the time is set to 0.0 s, the automatic reset of the horn output is disabled. The horn will remain ON until the alarm is acknowledged by the operator. Now, the status of the alarm changes from unacknowledged (UN-ACK.) to acknowledged (ACK.).

If the alarm condition is gone when the alarm is acknowledged, then the specific alarm message also disappears.

The GPU has two transistor outputs, each representing a value for the power production. The outputs are pulse outputs, and the pulse length for each of the activations is 1 second.

Term.number	Output
20	kWh
21	kVArh
22	Common terminal

The number of pulses depends on the actual adjusted setting of the nominal power:

Generator power	Value	Number of pulses (kWh)	Number of pulses (kVArh)
P_{NOM}	< 100 kW	1 pulse/kWh	1 pulse/kVArh
P_{NOM}	100-1000 kW	1 pulse/10 kWh	1 pulse/10 kVArh
P_{NOM}	> 1000 kW	1 pulse/100 kWh	1 pulse/100 kVArh

The kWh measurement is shown in the display as well, but the kVArh measurement is only available through the transistor output.

Be aware that the maximum burden for the transistor outputs is 10 mA.

The unit has the possibility to display different languages. It is delivered with one master language which is English. This is the default language, and it cannot be changed. In addition to the master language, 11 different languages can be configured. This is done via the PC utility software "Translations" function.

The active language is selected in menu 6080. The language can be changed when connected to the PC utility software. It is not possible to make language configuration from the display, but already configured languages can be selected.

SETUP + ⏎	GPU Hydro V 3.00.0 2010-01-01 04:26:02 SETUP MENU SETUP V3 V2 V1
SYST + ⏎	G 0 0 0V G f-L1 0.00Hz PROTECTION SETUP PROT CTRL I/O SYST
GEN + ⏎	G 0 0 0V SYSTEM SETUP GENERAL SETUP GEN MAINS COMM
6080 + ⏎	G 0 0 0V 6080 Language English LANG
LANG + ⏎ + △ or ▽ SAVE + ⏎	G 0 0 0V 6081 Language English RESET SAVE

The M-Logic functionality is included in the unit and is not an option-dependent function; however, selecting additional I/O options can increase the functionality.

M-Logic is used to execute different commands at predefined conditions. M-Logic is not a PLC but substitutes one, if only very simple commands are needed.

M-Logic is a simple tool based on logic events. One or more input conditions are defined, and at the activation of those inputs, the defined output will occur. A great variety of inputs can be selected, such as digital inputs, alarm conditions and running conditions. A variety of the outputs can also be selected, such as relay outputs, change of genset modes and change of running modes.

The M-Logic is part of the PC utility software, and as such it can only be configured in the PC utility software and not via the display.

The main purpose of M-Logic is to give the operator/designer more flexible possibilities of operating the generator control system.

Please refer to the document "Application notes, M-Logic" for a description of this configuration tool.

Generator

The nominal settings can be changed to match different voltages and frequencies. The GPU has four sets of nominal values, and they are adjusted in menus 6000 to 6030 (nominal settings 1 to 4).

The possibility to switch between the four sets of nominal setpoints is typically used in applications where switching between 50 and 60 Hz is required.

Activation

The switching between the nominal setpoints can be done in three ways: digital input, AOP or menu 6006.

Digital input

M-Logic is used when a digital input is needed for switching between the four sets of nominal settings. Select the required input among the input events, and select the nominal settings in the outputs.

Example:

Event A		Event B		Event C	Output
Dig. input no. 115	or	Not used	or	Not used	Set nom. parameter settings 1
Not Dig. input no. 115	or	Not used	or	Not used	Set nom. parameter settings 2

See the "Help" file in the PC utility software for details.

AOP

M-Logic is used when the AOP is used for switching between the four sets of nominal settings. Select the required AOP push-button among the input events, and select the nominal settings in the outputs.

Example:

Event A		Event B		Event C	Output
Button07	or	Not used	or	Not used	Set nom. parameter settings 1
Button08	or	Not used	or	Not used	Set nom. parameter settings 2

See the "Help" file in the PC utility software for details.

Menu settings
In menu 6006, the switching is made between settings 1 to 4 simply by choosing the desired nominal setting.

The GPU-3 has several relay outputs available. Each of these relays can be given a special function depending on the required functionality. This is done in the I/O setup (menu 5000-5270).

Relay functions

Function	Description
Alarm NE	The relay is activated until the alarm that caused the activation is acknowledged and gone. The alarm LED is flashing or constant, depending on the acknowledged state.
Limit	The relay will activate at the limit setpoint. No alarm will appear when both outputs (OA/OB) of the alarm are adjusted to the limit relay. After the condition activating this relay has returned to normal, the relay will deactivate when the "OFF delay" has expired. The OFF delay is adjustable.
Horn	The output activates on all alarms. For a detailed description, please refer to the chapter "Horn output".
Alarm/reset	The functionality is similar to "Alarm", but with a short-time reset (menu 5002) if the relay is ON and another alarm, set to the same relay, is activated.
Siren	The output activates on all alarms, like "Horn output". If the relay is ON and another alarm is active, a short-time reset = 1 sec will be activated.
Alarm ND	The relay is activated until the alarm that caused the activation is acknow-ledged and gone. The alarm LED is flashing or constant, depending on the acknowledged state.
Common alarm	The output activates on all alarms, just like the "Horn" function. If the relay is ON and another alarm is active, a short-time reset will be activated. The common alarm output will be activated as long as there is an active alarm, also if the alarm is acknowledged.

The GPU-3 has a self-check function and a status relay output that responds to this function. The status relay is prepared for 24V DC/1 A, and it is normally energised.

The self-check is monitoring the programme execution. Should this fail, i.e. in the unlikely event of microprocessor failure, then the self-check function deactivates the status relay.

Use the output from the status relay to perform a proper action for the genset application. Typically, this would mean a shutdown of the genset since it is now operating without protection and control.

The protections in the GPU-3 are not functioning when the self-check function deactivates the status relay.

There are two "Self-check ok" LEDs on the GPU-3. One is placed on the display and one on the main unit. The LEDs are lit when the unit is fully operational.

The purpose of the service menu is to give information about the present operating condition of the genset. The service menu is entered using the "JUMP" push-button (9120 Service menu).

Use the service menu for easy troubleshooting in connection with the event log.

Entry window
The entry window shows the possible selections in the service menu.

```
G        0        0        0V
9120 Service menu
Timers
TIME      IN      OUT       MISC
```

TIME
Shows the alarm timer and the remaining time. The indicated remaining time is minimum remaining time. The timer will count downwards when the setpoint has been exceeded.

```
G        0        0        0V
1010  G    -P>              2
Remaining time            1.0s
UP   DOWN
```

IN (digital input)
Shows the status of the digital inputs.

```
G        0        0        0V
Digital input   108
Input  =                    1
UP   DOWN
```

OUT (digital output)
Shows the status of the digital outputs.

```
G        0        0        0V
Relay  96
Output  A                   0
UP   DOWN
```

MISC
Shows the status of the M-Logic.

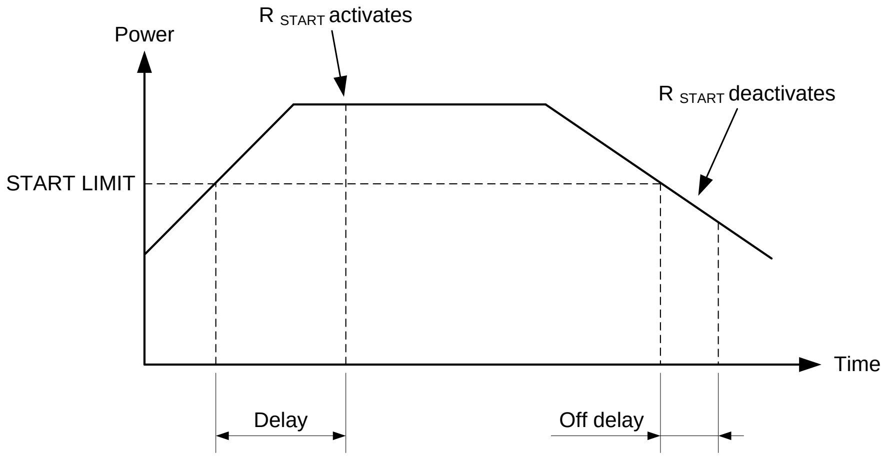
```
G        0        0        0V
M-Logic enabled
Various  =        1
UP   DOWN
```

The load-dependent start/stop functionality uses one relay for **start next generator** and one relay for **stop next generator**. It is also possible just to use one of the functions if it is not desired to use both the start and the stop function.

The function load-dependent start and stop does not give the possibilities of a power management system, such as priority selection and available power calculations. This means that the switchboard manufacturer must take care of starting and stopping the next genset(s) and their priority.

The relays can be used as inputs for the power management system as an example.

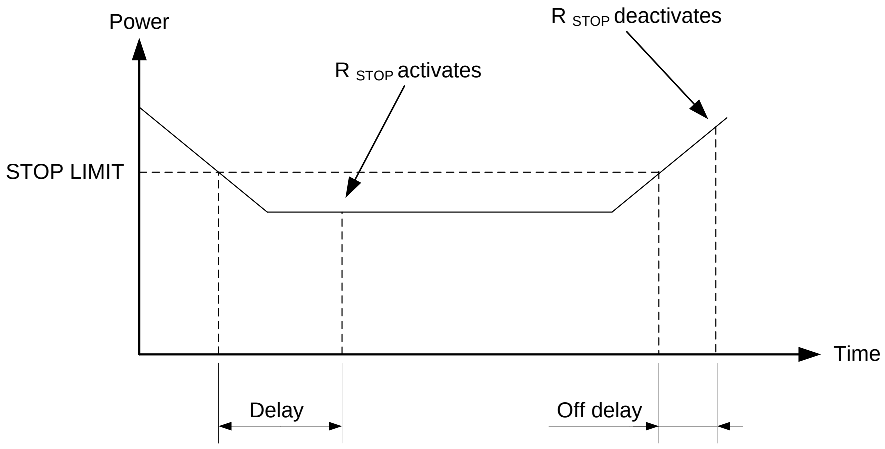
Start next generator (high load) (menu 6520)
The below diagram shows that the delay for the start relay starts when the load exceeds the adjusted start limit. The relay will deactivate again when the load decreases below the start limit and the off delay has expired.



The load-dependent start relay reacts based on the power measurement of the GPU together with the breaker closed feedback.

Stop next generator (low load) (menu 6530)
The diagram shows that the stop relay activates after a delay. The timer starts when the load drops below the adjusted stop level, and when the delay has expired, the relay activates.

The relay deactivates when the load exceeds the stop level when the off delay has expired. The off delay is adjustable.

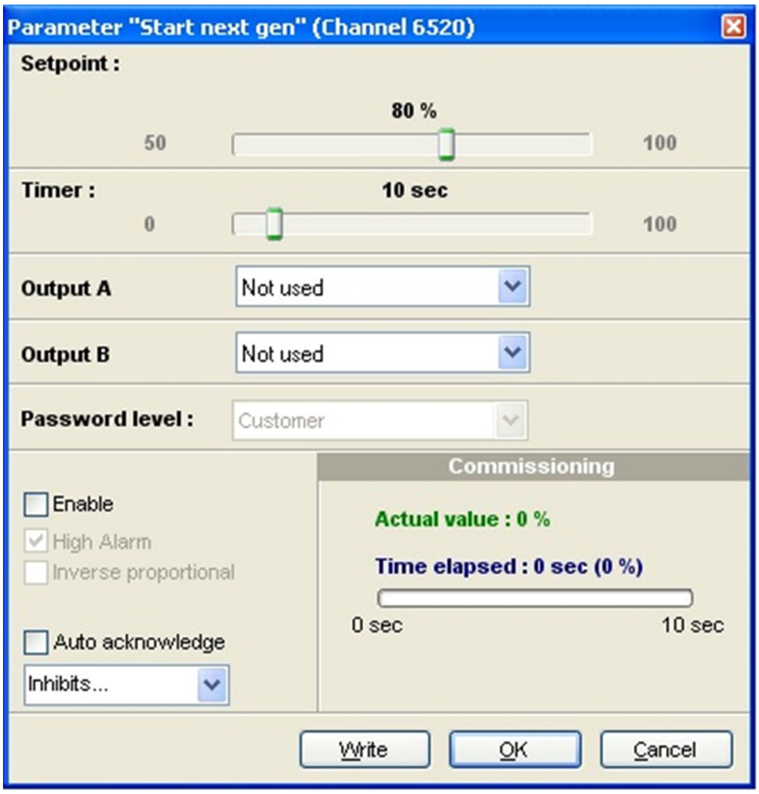


The load-dependent start relay reacts based on the power measurement of the GPU-3 together with the breaker closed feedback.

Configuration
The settings are configured through the display or through the PC utility software.

PC utility software configuration

Configuration of “Start next gen”:



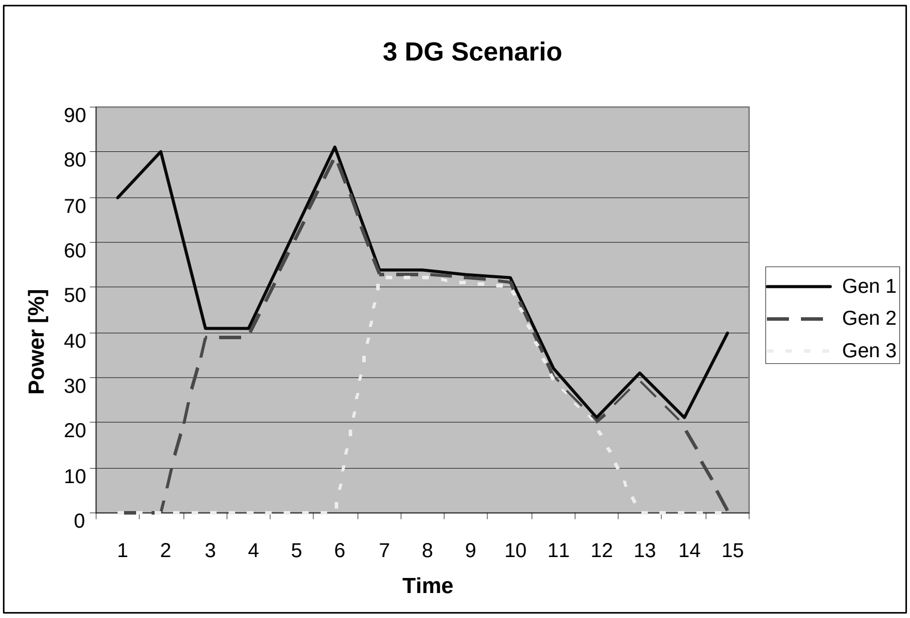
Output A and output B must be adjusted to the same relay to avoid alarms when the setpoint is reached.

When a relay has been selected for this function, it cannot be used for other functions.

Start/stop scenario
This diagram shows a (simplified) scenario where 3 DGs are started and stopped depending on the load-dependent start/stop relays.

The scenario shows that genset 2 starts when genset 1 reaches 80%. The next genset to start is DG3, and the three sets loadshare at 53%.

When the load of all three gensets drops to the stop limit, which is 20%, then the load-dependent stop relay activates and a genset (genset 3 in this example) can be stopped. The load continues to drop, and at 20% load the next genset to stop is genset 2.



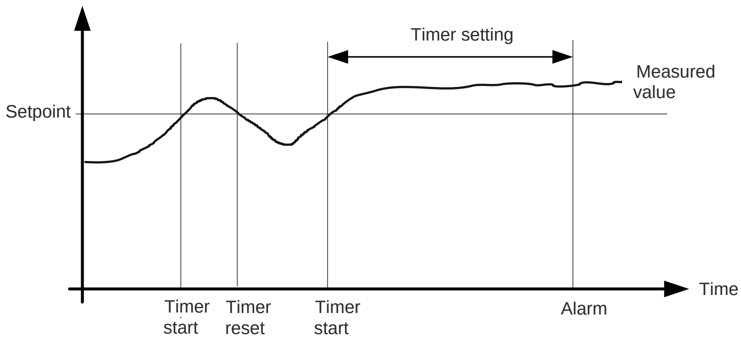
The above is a simplified scenario.

5. Protections

5.1 General

The protections are all of the definite time type, i.e. a setpoint and time is selected.

If the function is e.g. overvoltage, the timer will be activated if the setpoint is exceeded. If the voltage value falls below the setpoint value before the timer runs out, then the timer will be stopped and reset.



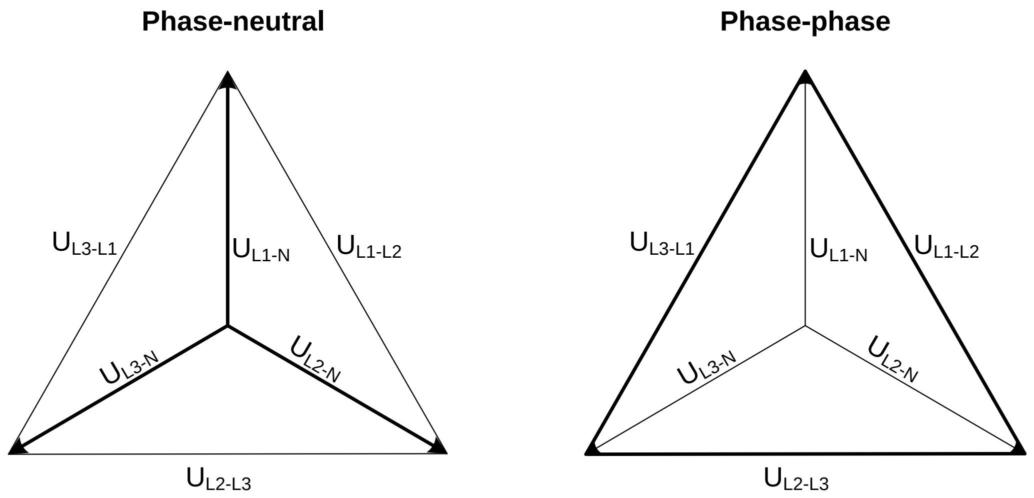
When the timer runs out, the output is activated.

When parameterising the DEIF controller, the measuring class of the controller and an adequate "safety" margin has to be taken into consideration.

An example: A power generation system must not reconnect to a network when the voltage is 85% of Un +/-0% ≤ U ≤ 110% +/-0%. In order to ensure reconnection within this interval, a control unit's tolerance/accuracy (Class 1 of the measuring range) has to be taken into consideration. It is recommended to set a control unit's setting range 1-2% higher/lower than the actual setpoint if the tolerance of the interval is +/-0% to ensure that the power system does not reconnect outside the interval.

5.2 Phase-neutral voltage trip

If the voltage alarms must work based on phase-neutral measurements, please adjust menus 1200 and 1340. Depending on the selections, either phase-phase voltages or phase-neutral voltages will be used for the alarm monitoring.



As indicated in the vector diagram, there is a difference in voltage values at an error situation for the phase-neutral voltage and the phase-phase voltage.

The table shows the actual measurements at a 10% undervoltage situation in a 400/230 volt system.

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

The alarm will occur at two different voltage levels, even though the alarm setpoint is 10% in both cases.

Example

The below 400V AC system shows that the phase-neutral voltage must change 20%, when the phase-phase voltage changes 40 volts (10%).

Example:

U_{NOM} = 400/230V AC

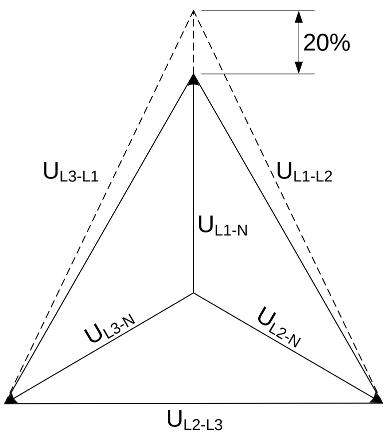
Error situation:

U_{L1L2} = 360V AC

U_{L3L1} = 360V AC

U_{L1-N} = 185V AC

ΔU_{PH-N} = 20%

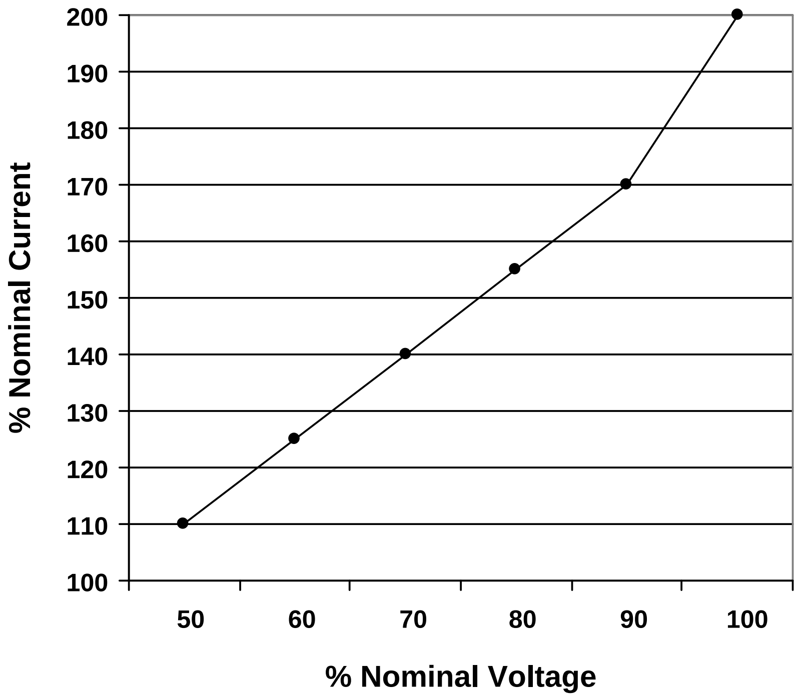


Phase-neutral or phase-phase: Both the generator protections and the busbar protections use the selected voltage.

5.3 Voltage-dependent (restraint) overcurrent

The protection calculates the overcurrent setpoint as a function of the measured voltage on the generator voltage terminals.

The result can be expressed as a curve function:



This means that if the voltage drops, the overcurrent setpoint will also drop.

The voltage values for the 6 points on the curve are fixed; the current values can be adjusted in the range 50-200%.

Voltage and current % values refer to the nominal settings.

Timer value can be adjusted in the range 0.1-10.0 sec.

5.4 Protections

5.4.1 Vector jump and df/dt protections

The loss of mains protection package includes df/dt (Rate Of Change Of Frequency, ROCOF) and/or vector jump protection. The protections are used when the generator is paralleling with the mains.

Measurement

Both the df/dt and vector jump protections are based on 3 individual single-phase measurements (individual monitoring of phases L1, L2 and L3). Therefore, the relay will trip if a df/dt and/or vector jump occurs in one of the 3 phases.

Principle

The vector jump and df/dt protections are intended for detection of a mains failure and subsequent opening of the mains breaker. The reasons are:

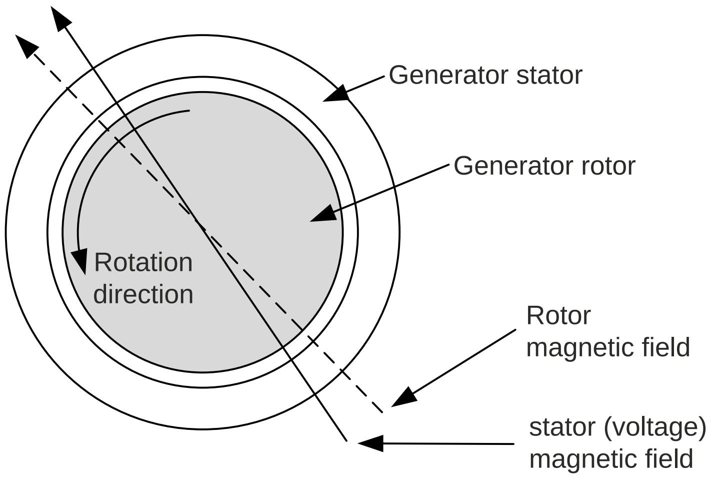
1. In case of mains failure the generator will run ”stand-alone” on the grid, attempting to supply power to all consumers. Naturally, this is not possible because of the mains failure, and an overload/overcurrent situation is likely to be the final result, as the mains consumption normally exceeds the generator capacity.
2. Mains transformer protection systems are constructed with a so-called ”fast reclosing” feature. This means that if a failure occurs (e.g. a short circuit), then the transformer protection system will open the transformer breaker. But after a while (the actual time period depends on the specific country; e.g. 330ms in Denmark), the breaker will be reclosed to check whether it was a short-time failure, e.g. 2 overhead wires meeting shortly, a lightning stroke, a branch falling down from a tree, etc. If the failure is still present, the breaker will be reopened and remain there.

This reclosing combined with the high overload on the generator means that the generator and the mains will be paralleled again without synchronisation, an operation which will most likely damage the entire gen-set.

Ordinary protections will not identify a mains failure before it is too late (300ms). Therefore, the vector jump and/or df/dt protections are used. These will detect the mains failure and open the breaker before reclosing occurs.

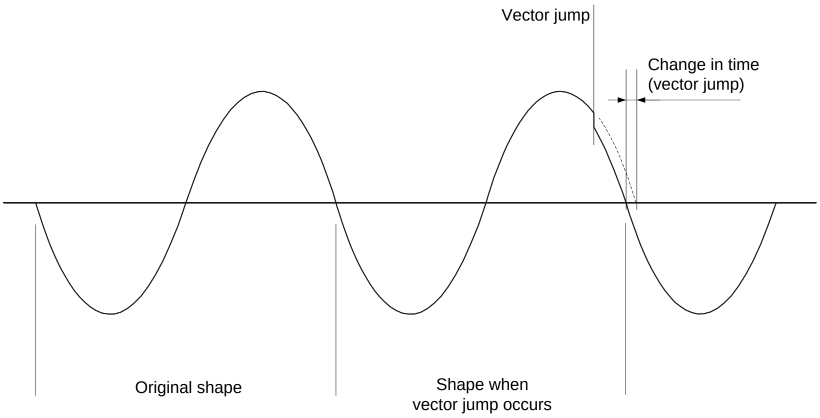
Vector jump

Vector jump is based on the fact that the stator magnetic field – and as a result, the 3-phase voltage from a generator lags a little behind the rotor magnetic field (in time and position).



If a mains failure occurs, the time lag of the stator magnetic field (and the output voltage) will change (jump). This is called a vector jump.

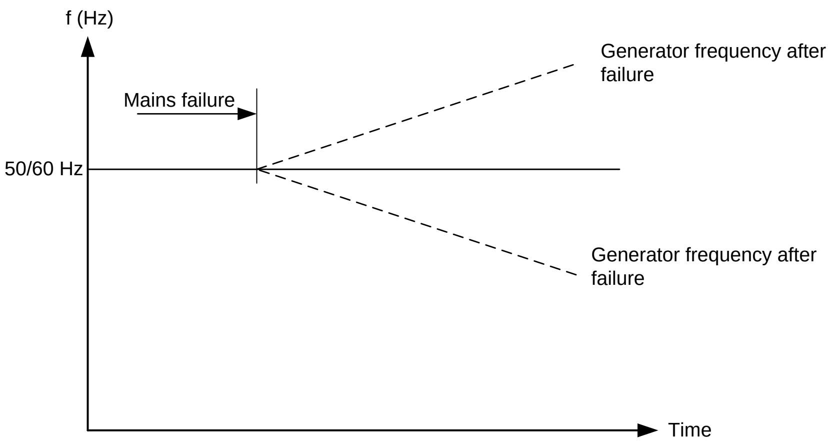
A vector jump illustrated in a sine wave:



Again, comparing the half-sine curve time duration with the previous ones, a sudden change in time can be detected. This is the vector jump.

The vector jump setting is made in electrical degrees. The vector jump has no delay setting, since it reacts instantaneously. The delay will be the reaction time.

df/dt (ROCOF)
The df/dt function is based on the fact that the generator, if overloaded, will loose speed dramatically. Alternatively, it will speed up dramatically if a lot of load is dropped instantly.



So, a dramatic drop/increase of frequency over time is a mains failure. The df/dt setting is made in Hz/s.

The delay is set in periods, i.e. if the setting is set to ”6per” (factory setting), the time delay will be 120 ms (50 Hz) or 100 ms (60 Hz). The total delay will be the delay setting + reaction time.

Adjustments

Load jumps

Vector jump and df/dt protections are generally very reliable when used for generator protection to avoid asynchronous reconnection of the generator to the mains after a mains failure.

Nevertheless, the protections may fail to react if no or a very small load change takes place upon mains failure. This can happen when the generator is used in a peak lopping or Combined Heat and Power (CHP) system, where the power flow to the mains is very low.

In general, the system load change necessary to activate the vector jump or the df/dt protections is 15-20% of the plant's rated power. Attempting to increase the sensitivity of the protection by lowering the setpoint value may result in false trips, because even the mains grid is not completely stable.

Distant mains breaker decoupling
If a mains failure occurs in a system where a generator is running as a peak lopping/automatic mains failure generator, and if the loss of mains protection is used to decouple a mains breaker, care must be taken to prevent the generator breaker short circuit from tripping the generator breaker before the mains breaker is tripped.

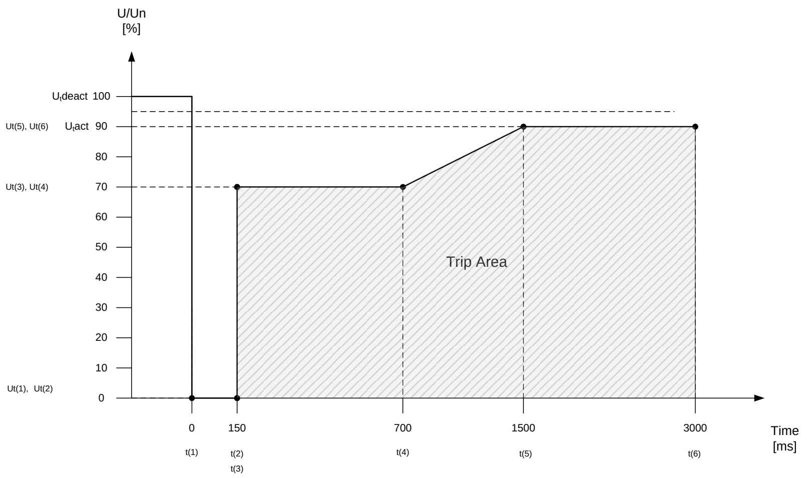
This may happen if the mains failure is a distant one, because it will leave so many remaining consumers connected to the gen-set that they will appear to be a short circuit when compared to the generator nominal current.

Compare the reaction time + the delay time of the vector jump/df/dt protection to the delay time of the generator breaker short circuit protection to determine whether this is a problem.

5.4.2 Time-dependent undervoltage

The time-dependent undervoltage protection is defined by 6 curve points. Each point consists of a voltage limit value and a time delay. The protection will activate if any phase-phase voltage at any given time drops below the set voltage value (below the curve). Between any 2 neighbouring points, the resulting curve is a straight line.

Example:



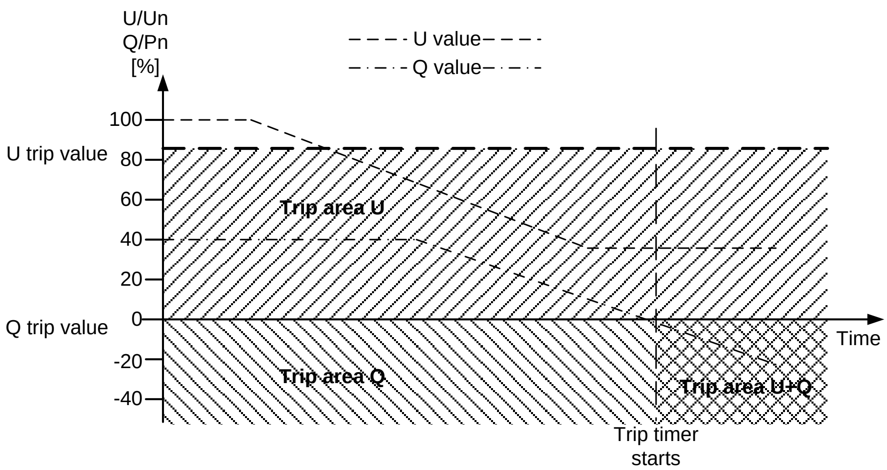
$U_t$reset:	The voltage level in % of nominal voltage where the function is reset (function timer stops and resets).
$U_t$act:	The voltage level in % of nominal voltage where the function is activated (function timer starts running).
$U_t(1)$-$U_t(6)$:	The voltage setpoints in % of nominal voltage.
t(1)-t(6):	The time in ms corresponding to the voltage setpoint.

U_t can be set as low as 30V AC, meaning that the trip curve is horizontal and no trip will take place during the time t(1) to t(2). If the setting $U_t(1)$ has a value of 30%, the underfrequency alarms are inhibited until the time reaches the value t(2). The settings $U_t(2)$ to $U_t(6)$ will not affect the underfrequency alarm.

5.4.3 U and Q low

The function U_Q< is active as soon as all three phase-phase generator voltages go below the voltage limit value and the reactive power is equal to or below 0 (zero) at the same time. Tripping takes place if the function is active for more than the adjusted delay $t(U_Q<)$.

The practical meaning of this is that the generator has no stabilising effect for the disturbed grid and therefore must be disconnected.



The reactive power Q [%] is related to the generator nominal power P_{nom}.

The positive reactive power area is representing inductive values. The negative reactive power area is representing capacitive values. The reactive power values (inductive/capacitive) are values seen from the generator side, i.e. inductive values represent the generator delivering reactive power into the mains grid.

5.4.4 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 unit is able to trip three 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 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.

6. PID controller (option G2)

6.1 General

Frequency control requires option G2.

The PID controller consists of a proportional regulator, an integral regulator and a differential regulator. The PID controller is able to eliminate the regulation deviation and can easily be tuned in.

For details about tuning the controllers, please refer to the “General Guidelines for Commissioning”.

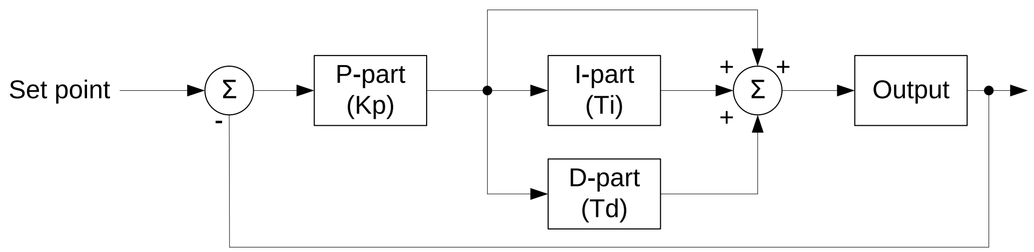
6.2 Controllers

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

Controller	GOV	AVR	Comment
Frequency sync.	X		Controls the frequency during synchronisation (GB OFF)
Frequency	X		Controls the frequency when the GB is open
Voltage (option D1)		X	Controls the voltage when the GB is open

6.3 Principle drawing

The drawing below shows the basic principle of the PID controller.



$$\mathrm{PID}(s) = Kp \cdot \left(1 + \frac{1}{Ti \cdot s} + Td \cdot s\right)$$

As illustrated in the above drawing and equation, each regulator (P, I and D) gives an output which is summarised to the total controller output.

The adjustable settings for the PID controllers in the GPU-3 unit are:

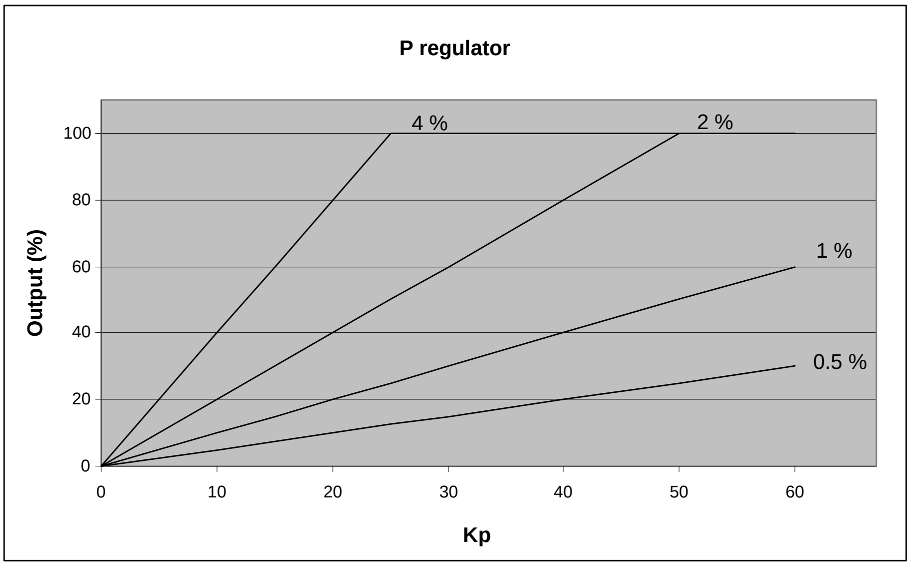
Kp: The gain for the proportional part.
Ti: The integral action time for the integral part.
Td: The differential action time for the differential part.

The function of each part is described in the following.

6.4 Proportional regulator

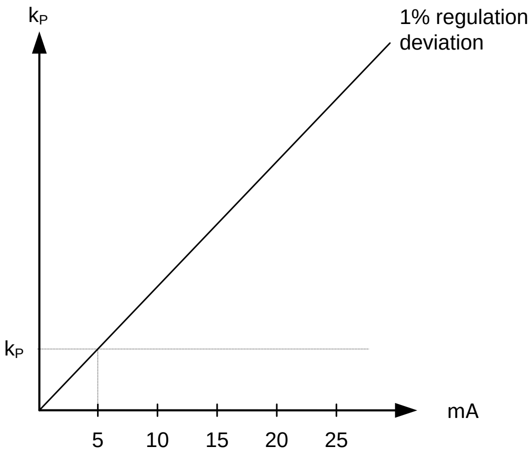
When the regulation deviation occurs, the proportional part will cause an immediate change of the output. The size of the change depends on the gain Kp.

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

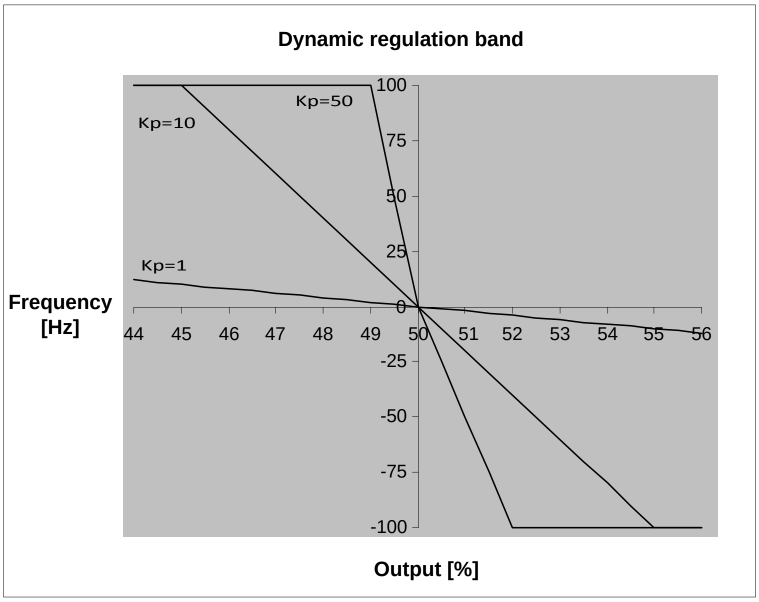
Because of the characteristic above, it is recommended to use the full range of the output to avoid an unstable regulation. If the output range used is too small, a small regulation deviation will cause a rather big output change. This is shown in the drawing below.



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

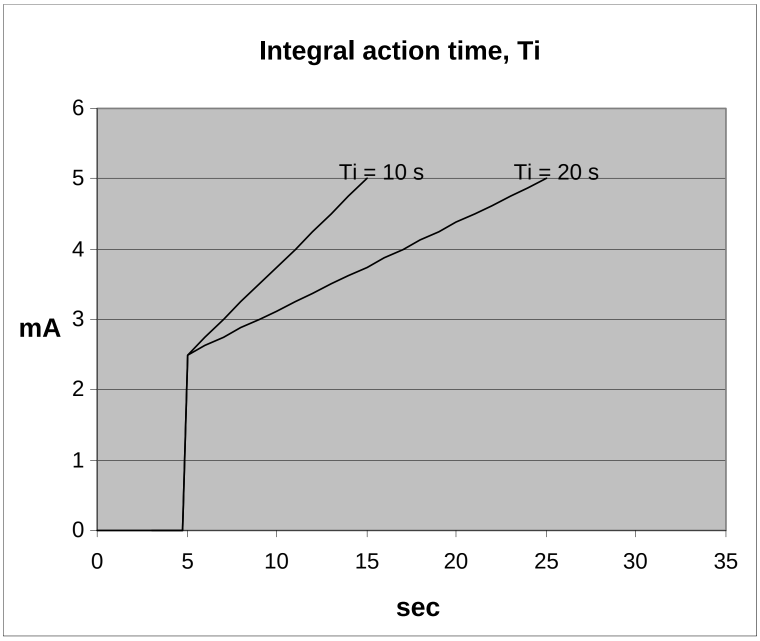
Max. speed range	Output change		Output change in % of max. speed range
10 mA	5 mA	5/10*100%	50
20 mA	5 mA	5/20*100%	25

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
The main function of the integral regulator is to eliminate offset. The integral action time, Ti, 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 2.5 mA. The integral action time is then measured when the output reaches 2 x 2.5 mA = 5 mA.



As it appears from the drawing, the output reaches 5 mA twice as fast at a Ti setting of 10 s than with a setting of 20 s.

The integrating function of the I-regulator is increased if the integral action time is decreased. This means that a lower setting of the integral action time, Ti, results in a faster regulation.

If the Ti is adjusted to 0 s, the I-regulator is switched OFF.

The integral action time, Ti, must not be too low. This will make the regulation hunt, similar to a too high proportional action factor, Kp.

Differential regulator

The main purpose of the differential regulator (D-regulator) is to stabilise the regulation, thus making it possible to set a higher gain and a lower integral action time, Ti. This will make the overall regulation eliminate deviations much faster.

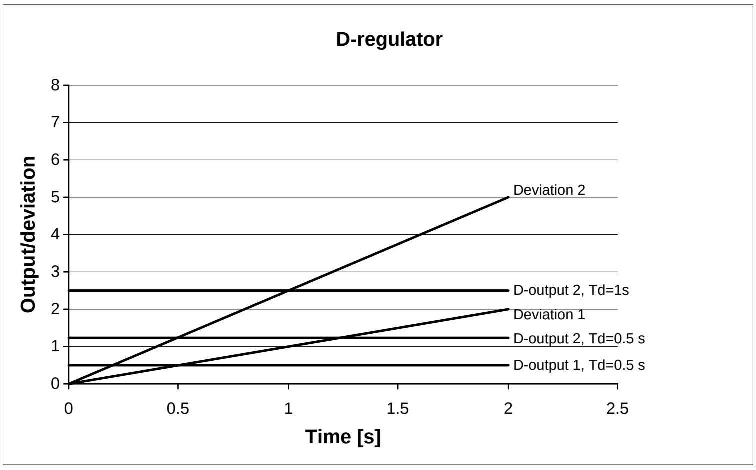
In most cases, the differential regulator is not needed; however, in case of very precise regulation situations, e.g. static synchronisation, it can be very useful.

The output from the D-regulator can be explained with the equation: $D = Td \cdot Kp \cdot \frac{de}{dt}$

D = regulator output
Kp = gain
de/dt = slope of the deviation (how fast does the deviation occur)

This means that the D-regulator output depends on the slope of the deviation, the Kp and the Td setting.

Example:
In the following example, it is assumed that Kp = 1.



Deviation 1:	A deviation with a slope of 1.
Deviation 2:	A deviation with a slope of 2.5 (2.5 times bigger than deviation 1).
D-output 1, Td=0.5 s:	Output from the D-regulator when Td=0.5 s and the deviation is according to Deviation 1.
D-output 2, Td=0.5 s:	Output from the D-regulator when Td=0.5 s and the deviation is according to Deviation 2.
D-output 2, Td=1 s:	Output from the D-regulator when Td=1 s and the deviation is according to Deviation 2.

The example shows that the bigger deviation and the higher Td setting, the bigger output from the D-regulator. Since the D-regulator is responding to the slope of the deviation, it also means that when there is no change, the D-output will be zero.

When commissioning, please keep in mind that the Kp setting has influence on the D-regulator output.

If the Td is adjusted to 0 s, the D-regulator is switched OFF.

The differential action time, Td, must not be too high. This will make the regulation hunt, similar to a too high proportional action factor, Kp.

6.5 Manual governor and AVR control

This function can be activated by pressing the ▽ push-button for more than two seconds. The intention of this function is to give the commissioning engineer a helpful tool for adjustment of the regulation.

The function of the regulation window depends on the selected mode:

G 0	0	0V
P-Q Setp	100%	100%
P-Q Reg.	50%	60%
	GOV	AVR

Manual mode
In manual mode, the regulation is deactivated. When activating the up or down arrow, the output value to GOV or AVR is changed; this is the “Reg.” value in the display. The up and down arrows have the same function as the digital inputs or AOP buttons for governor and AVR control when the window is open. To exit the regulation window, press “Back”.

Local/remote mode
As in manual mode, the up and down arrows have the same function as the digital inputs or AOP buttons for governor or AVR control when the window is open.

The value “Setp” can be changed by pressing the up or down arrow. When GOV is underlined, the governor setpoint will be changed, and vice versa when AVR is underlined. When changing the “Setp” value, an offset will be added to or subtracted from the nominal value. The “Reg.” value is the output value from the regulator. If the genset is running in fixed P/Q, the active or reactive nominal power setpoint value will be changed. In fixed frequency/voltage, the nominal frequency or voltage setpoint will be changed and also displayed. When the “Back” button is activated, the regulation setpoint returns to nominal.

Voltage control requires option D1 in addition to option G2.

Regarding AOP setup, please refer to “Help” in the PC utility software.

7. Synchronisation (option G2)

7.1 General

Synchronisation requires option G2.

With the option G2 enabled, the unit can be used for 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.

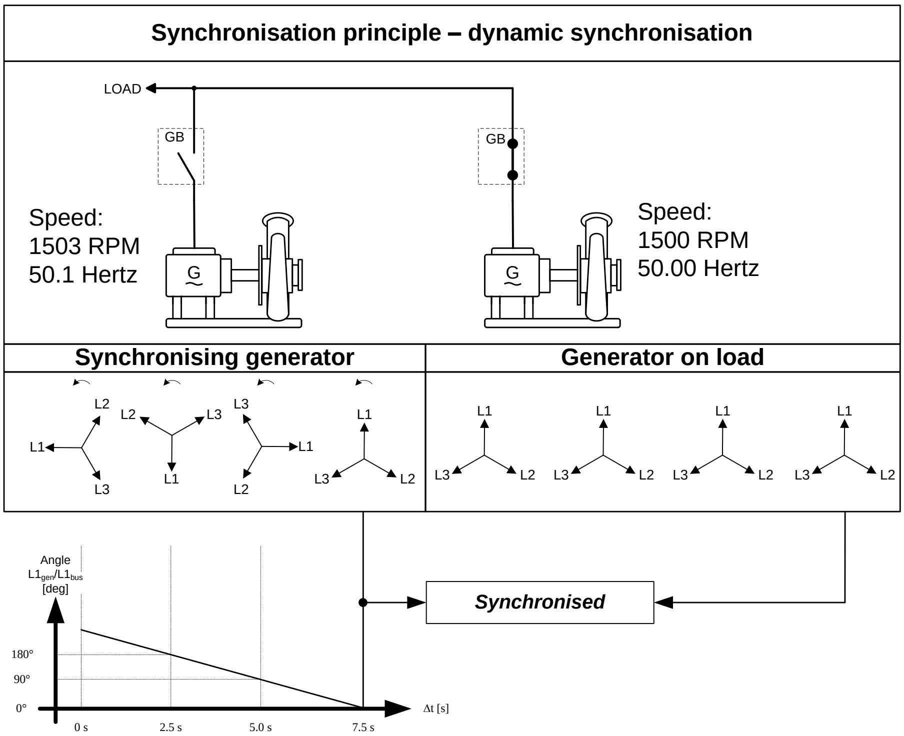
In the following, the term "synchronisation" means "synchronising and closing of the synchronised breaker".

When the breaker has been closed, the regulator is deactivated.

7.2 Dynamic synchronisation

In dynamic synchronisation, the synchronising genset is running at a different speed than the generator on the busbar. This speed difference is called **slip frequency**. Typically, the synchronising genset is running with a positive slip frequency. This means that it is running with a higher speed than the generator on the busbar. The objective is to avoid a reverse power trip after the synchronisation.

The dynamic principle is illustrated below.



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

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 genset 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. The reason is that 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 0.1 Hz 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 above illustration, the difference in the phase angle between the synchronising set and the busbar gets smaller and will eventually be zero. Then the genset 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 0.1 Hz):

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

The synchronisation pulse is always issued, so the closing of the breaker will occur at the 12 o'clock position.

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

Load picture after synchronising

When the incoming genset 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 genset will *export* power to the load. Illustration 2 below shows that at a given *negative* slip frequency, the incoming genset will *receive* power from the original genset. 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.

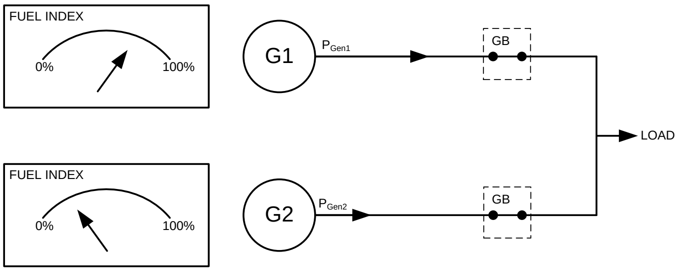


Illustration 1, POSITIVE slip frequency

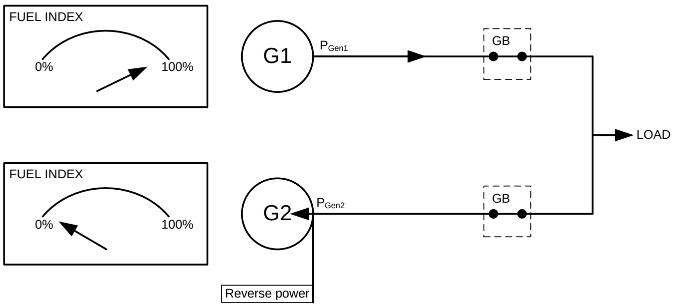


Illustration 2, NEGATIVE slip frequency

Adjustments

The dynamic synchroniser is selected in menu 2010 in the control setup and is adjusted in menu 2020 Sync.

Setting	Description	Comment
2021 f_{MAX}	Maximum slip frequency	Adjust the maximum positive slip frequency where synchronising is allowed
2022 f_{MIN}	Minimum slip frequency	Adjust the maximum negative slip frequency where synchronising is allowed
2023 U_{MAX}	Maximum voltage difference (+/- value)	The maximum allowed voltage difference between the busbar/mains and the generator
2024 t_{GB}	Generator breaker closing time	Adjust the response time of the generator breaker

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 setpoint, synchronising can still occur as long as the frequency is within the limits of the slip frequency adjustments.

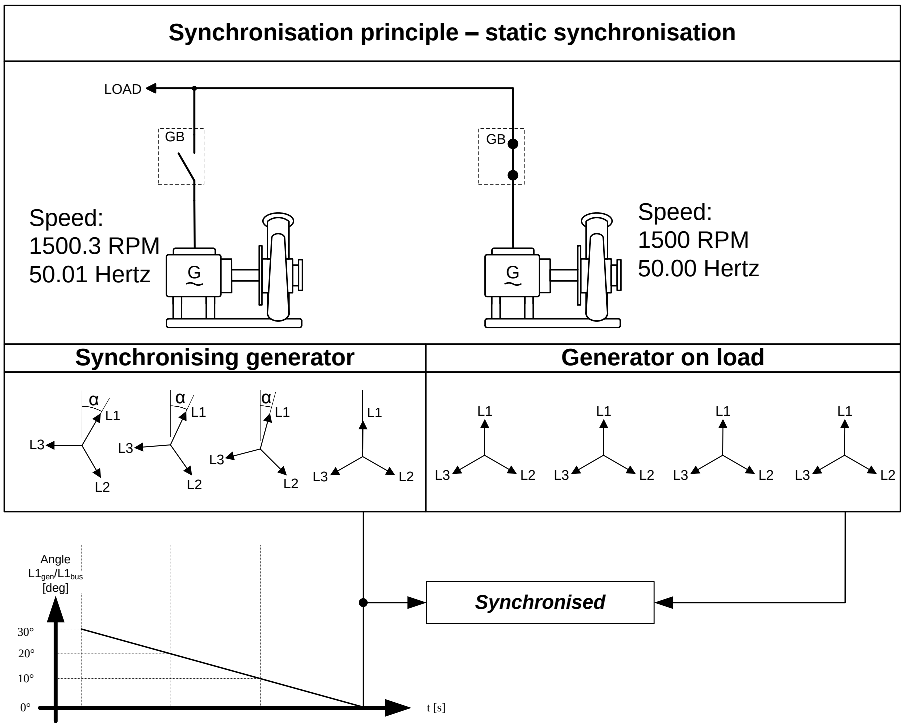
Dynamic synchronisation is recommended where fast synchronisation is required, and where the incoming gensets are able to take load just after the breaker has been closed.

7.3 Static synchronisation

In static synchronisation, the synchronising genset 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.

Due to the slower nature of the regulation with relay outputs, it is not recommended to use the static synchronisation principle when relay regulation outputs are used.

The static principle is illustrated below.



Phase controller

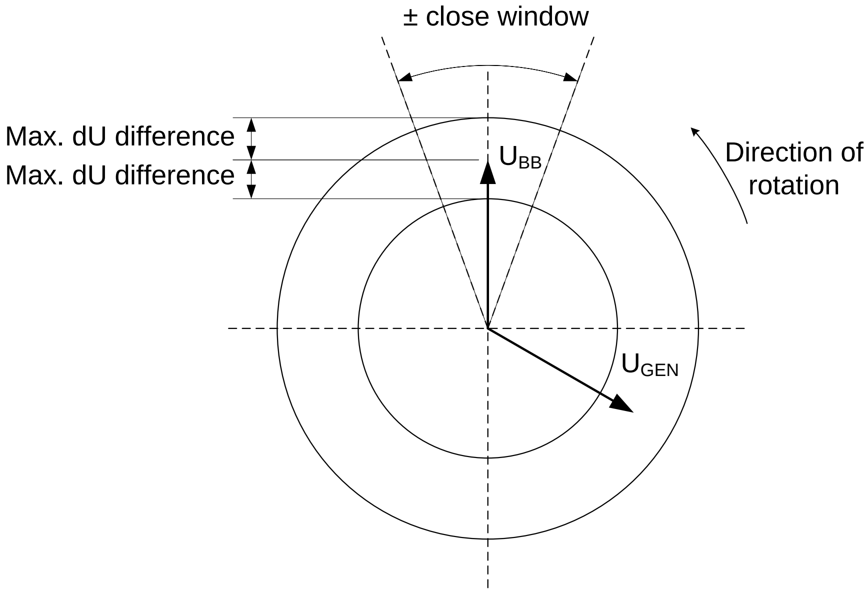
When the static synchronisation is used and the synchronising is activated, the frequency controller will bring the genset frequency towards the busbar frequency. When the genset frequency is within 50 mHz of the busbar frequency, then the phase controller takes over. This controller uses the angle difference 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 setpoint. The range is +/-0.1-20.0 deg. This is illustrated in the drawing below.



The synchronisation pulse is sent according to the settings in menu 2030 Sync.

Load picture after synchronisation
The synchronised genset 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.

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

Settings

The following settings must be adjusted, if the static synchroniser is selected:

Setting	Description	Comment
Maximum df	The maximum allowed frequency difference between the busbar/mains and the generator	+/- value
Maximum dU	The maximum allowed voltage difference between the busbar/mains and the generator	+/- value, related to the nominal generator voltage
Close window	The size of the window where the synchronisation pulse can be released	+/- value
Phase K_p	Adjustment of the proportional part of the PID phase controller	Only used during static synchronisation
Phase Ti	Adjustment of the integral part of teh PID phase controller	
Phase Td	Adjustment of the differential part of the PID phase controller	

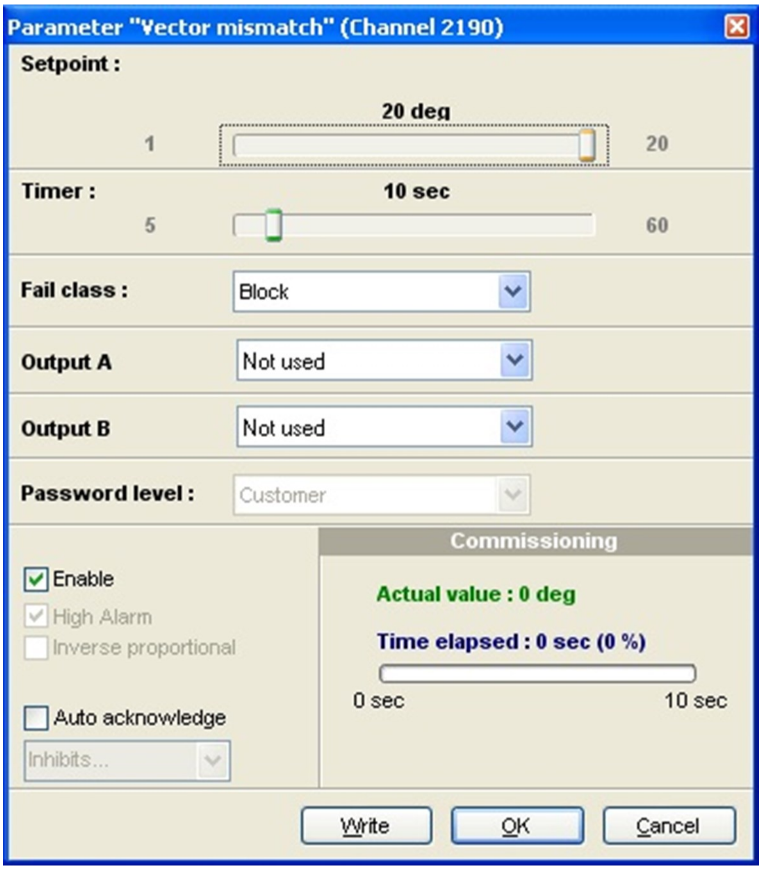
7.4 Synchronising vector mismatch alarm

During synchronisation, the calculation and synchronisation check is based on BB-L1 and DG-L1 measurements.

The “vector mismatch” alarm (menu 2190) will appear if a phase angle difference between BB L2/L3 and Gen L2/L3 is above 20 deg.

The vector mismatch alarm will by default block the GB close sequence, but the fail class can be configured in parameter 2196.

If the phase sequence does not match (e.g. cable mounted incorrectly), a “Phase seq. error” will appear and block the GB close sequence.



The vector mismatch timer should be set to a value lower than the GB sync. failure timer (parameter 2131).

7.5 Asynchronous synchronisation

This function requires option M4 in addition to option G2.

Closing of a breaker for an asynchronous generator (also called induction generator) can be selected in menu 6361 where the selection of generator type is made. When the generator type is set to "asynchronous", the closing of the breaker is based on the MPU signal only.

Running feedback
The MPU input must be used as primary running feedback when the asynchronous generator is used. The start and operation of the generator requires that the nominal speed is adjusted (e.g. 1500 or 1800 RPM).

Breaker closing
When the genset is running, the GB can be closed in local or remote mode. During the GB close sequence, the speed setpoint will be:

RPM setpoint = RPM nom. + (RPM SLIP min. + RPM SLIP max.)/2.

The acceptable slip frequency is set in menu 2010.

When the speed setpoint is reached, the close GB signal is issued. After the GB has been closed and running has been detected on the voltage and frequency, the regulation mode will change according to the regulation mode inputs.

After the GB has been closed, the control of the "asynchronous" generator is the same as for the "synchronous" type.

7.6 Sequences

The following section contains information about the sequences of the GPU-3.

These sequences will be described:

Sequence	Description
GB ON	Synchronising
GB ON	Blackout closing
GB OFF	Open breaker

GB ON sequence/synchronising
The GB ON sequence can be started when the generator is running and the terminal 25 (start sync./control) is activated. The regulation will start and control the genset in order to synchronise the breaker.

The busbar voltage must be above 70% x U_{NOM} in order to initiate the synchronising.

Interruption of the GB ON (synchronising) sequence	
Input 25 deactivated	
Input 43 activated	25 ON at the same time
Remote GB ON activated	
GB close	
U_{BB} measured below 70%	70% x U_{NOM}
Synchronising failure	
GB close failure	
Alarm with Trip GB or Block fail class	

When the GB opens, there is a 10 s delay that prevents it from closing immediately after it has opened. This is to ensure that there is sufficient time to change mode and control inputs.

To activate the use of “Start sync./control” from M-Logic or external communication (e.g. Modbus), the M-Logic command “Start sync./ctrl enable” has to be activated. Alternatively, you can use the functions “Remote GB ON” and “Remote GB OFF”.

GB ON sequence/blackout closing
In order to make a blackout closing, terminal 25 must be activated and the measurements from the busbar must be missing. The breaker will close if the generator voltage is within the settings of 2110 “Sync. Blackout”.

The busbar voltage must be below 30% x U_{NOM} in order to initiate the black busbar closing.

Interruption of the GB ON (blackout close) sequence	
Input 25 deactivated	
Input 43 activated	25 ON at the same time
Remote GB ON activated	
U gen. not OK	Limit set in menu 2112
f gen. not OK	Limit set in menu 2111
Black closing not enabled	Input function configured and input not activated
GB close	
U_{BB} measured above 30%	
GB close failure	
Alarm with Trip GB or Block fail class	

To activate the use of "Start sync./control" from M-Logic or external communication (e.g. Modbus), the M-Logic command "Start sync./ctrl enable" has to be activated. Alternatively, you can use the functions "Remote GB ON" and "Remote GB OFF".

When the GB opens, there is a 10 s delay that prevents it from closing immediately after it has opened. This is to ensure that there is sufficient time to change mode and control inputs.

GB OFF/open breaker
The GB can be opened instantly by the GPU-3. The sequence is started by this selection of the control inputs:

Terminal	Description	Input state
25	Start sync./control	ON
43	Deload	ON

The GB open signal will be issued immediately when the combination of the control inputs are as mentioned in the table above.

7.7 Breaker types

There are three possible selections for the setting of the GB type (menu 6233).

Continuous
This type of signal is most often used combined with a contactor. When using this type of signal, the GPU will only use the close breaker relays. The relay will be closed for closing of the contactor and will be opened for opening of the contactor.

If continuous breaker is selected, Relay 14 will become configurable.

Pulse (default setting)
This type of signal is most often used with a motorised circuit breaker. With the setting pulse, the GPU will use the close command and the open command relay. The close breaker relay will close for a short time for closing of the circuit breaker. The open breaker relay will close for a short time for opening of the breaker.

Compact
This type of signal will most often be used with a compact breaker, a direct-controlled motor-driven breaker. With the setting compact, the GPU will use the close command and the open command relay. The close breaker relay will close for a short time for the compact breaker to close. The breaker off relay will close for the compact breaker to open and hold it closed long enough for the motor in the breaker to recharge the breaker. If the compact breaker is tripped externally, it is recharged automatically before next closing.

7.8 Breaker spring load time

To avoid breaker close failures in situations where breaker ON command is given before the breaker spring has been loaded, the spring load time can be adjusted for the GB.

The following describes a situation where you risk getting a close failure:

1. The genset is in remote mode, the “Start sync./control” input is active, the genset is running and the GB is closed.
2. The deload input is activated and the GB is opened.
3. If the deload input is deactivated again, the GB will give a GB close failure as the GB needs time to load the spring before it is ready to close.

Different breaker types are used, and therefore there are two available solutions:

1. Timer controlled
A load time setpoint for the GB control for breakers with no feedback indicating that the spring is loaded. After the breaker has been opened, it will not be allowed to close again before the delay has expired. The setpoint is found in menu 6230.

2. Digital input
A configurable input to be used for feedbacks from the breaker. After the breaker has been opened, it will not be allowed to close again before the configured input is active. The input is configured in the ML-2 utility software.

If the two solutions are used together, both requirements are to be met before closing of the breaker is allowed.

Breaker LED indication
To alert the user that the breaker close sequence has been initiated, but is waiting for permission to give the close command, the LED indication for the breaker will be flashing yellow in this case.

7.9 Separate synchronising relay

When the unit gives the synchronising command, then the relays on terminal 17/18/19 (generator breaker) will activate, and the breaker must close when this relay output is activated.

This default function can be modified using a digital input and extra relay outputs depending on the required function. The relay selection is made in the menu 2240, and the input is selected in the input settings in the utility software.

The table below describes the possibilities.

Input	**Relay selected** Two relays used	**Relay not selected** One relay used
Not used	**Synchronising:** The breaker ON relay and the sync. relay activate at the same time when synchronising is OK. **Blackout closing:** The breaker ON relay and the sync. relay activate at the same time when the voltage and frequency are OK.	**Synchronising:** The breaker ON relay activates when synchronising is OK. **Blackout closing:** The breaker ON relay activates when the voltage and frequency are OK. **DEFAULT selection**
Low	**Synchronising:** Not possible. **Blackout closing:** The breaker ON relay and the sync. relay activate at the same time when the voltage and frequency are OK.	**Synchronising:** Not possible. **Blackout closing:** The breaker ON relay activates when the voltage and frequency are OK.
High	**Synchronising:** The relays will activate in two steps when the synchronising is selected: 1. Breaker ON relay activates. 2. When synchronised, the sync. relay activates. **See note below!** **Blackout closing:** The breaker ON relay and the sync. relay activate at the same time when the voltage and frequency are OK.	**Synchronising:** Not possible. **Blackout closing:** The breaker ON relay activates when the voltage and frequency are OK.

When two relays are used together with the separate sync. input, then please notice that the breaker ON relay will be activated as soon as the GB ON/synchronising sequence is activated.

Care must be taken that the GB ON relay cannot close the breaker, before the sync. signal is issued by the sync. relay.

The selected relay for this function must have the “limit” function. This is adjusted in the I/O setup.

7.10 Step-up transformer

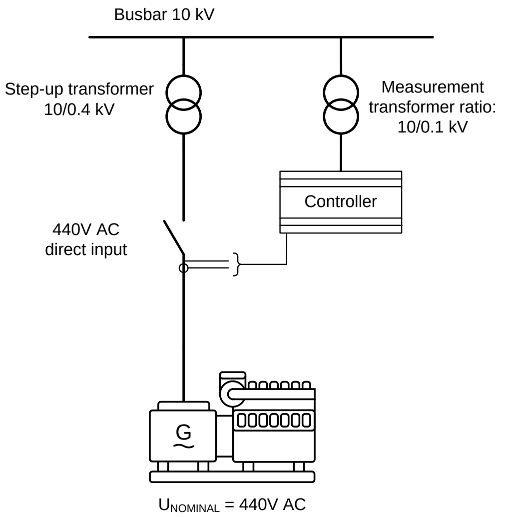
The GPU-3 can be used in applications where the generator is followed by a step-up transformer. I.e. the measurement of the generator voltage is on a different level than the measurement of the busbar voltage.

Applications
Different applications are supported by the GPU-3 when a step-up transformer is placed after a generator. Measurement transformers can be installed on the generator side and the busbar side, or direct inputs between 100V AC and 690V AC can be connected.

A typical setup includes a low voltage generator, e.g. 400V AC, and a step-up transformer, e.g. 400/10000V AC. In this case, 400V AC would be connected to the generator inputs and 100 or 110 from the measurement transformer connected to the busbar inputs.

Measurement transformer
The GPU-3 can be adjusted with different measurement transformer ratios. This is adjusted in the system setup (menus 4020/4030). The advantage is i.a. that synchronising of a circuit breaker can be performed, even though the voltage measurement points are not placed on the same busbar.

Different measurement inputs
In the GPU-3, it is possible to have different measurement inputs on the generator measurements and the busbar measurements. Schematically, it looks e.g. like the diagram below where the generator inputs are 440 volt and the busbar inputs are 100 volt.



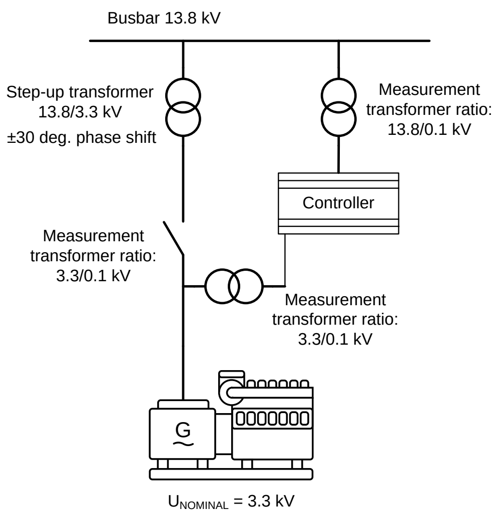
The current measurement point must be placed on the generator side of the step-up transformer.

If the transformer has an angle displacement, then synchronising can ONLY be used with Yy1, Dy1, Yd1, Yy11, Dy11 and Yd11 transformers. (+/-30 deg. phase shift).

The factory setting is 0 degrees, and it has to remain at that value except when one of the six mentioned transformers is installed between the generator and the busbar measurements.

Any error in this setting will cause a false closing of the breaker! Therefore it is essential to check the angular precision before allowing the GPU-3 to perform a real breaker closing.

Single-line example
The simple diagram below shows a step-up transformer with +/- 30 deg. phase shift depending on the type of transformer. In order to be able to synchronise the generator circuit breaker, the GPU must compensate for the 30 deg. offset.



When used for synchronising, the GPU-3 uses the ratio of the nominal voltages of the generator and the busbar when calculating the AVR setpoint and the voltage synchronising window (dU_{MAX}).

Example:
A 10000/400V AC step-up transformer is installed after a generator with the nominal voltage of 400V AC. The nominal voltage of the busbar is 10000V AC. Now, the voltage of the busbar is 10500V AC. The generator is running 400V AC before the synchronising starts, but when attempting to synchronise, the AVR setpoint will be changed to $U_{BUS\text{-}MEASURED} * U_{GEN\text{-}NOM}/U_{BUS\text{-}NOM}$:10500*400/10000 = 420V AC.