GPM500
Introduction

Revision 4.6

including Parameter tool and IDE

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Index	Description	Date	Author
3.0	IDE and tools added	23.01.06	Dr. Horn
3.1	Minor changes, “Voltage Restrained Overcurrent VRO” added, saved as .odf	16.01.08	Dr. Horn
3.2	p.44: Consumer contacts corrected	07.07.08	Dr. Horn
4.1	Modbus-Doc improved, Harbourgenerator added	28.05.09	Dr. Horn
4.2	Several small revisions: - Pictures included	07.09.09	Dr. Horn
4.3	UNIT11 extended	20.11.09	uh
4.4	Controller description extended	1/12/10	uh
4.5	DPM included	4/23/10	uh
4.6	Review before ZKG501	04/06/11	uh

DAY 1
UNIT 1 GPM500 philosophy

1.1 Target Group & Educational Aim

We have to cover the full range from sales personal to service personal. Most important question for all of them: What can GPM500 do? And even more important: What not?

1.2 History of the GPM500 & DPM500

The Generator Protection device GPM500 replaces the former devices GMM10, TPM10 and MPM10. This paper and course should provide an overview of protection and control functions of the GPM500. The internal Power Management System Geapas500 (which may be activated in the GPM500) will be described in addition.

The device is intended primarily as generator protection device, protection and control of transformers, tiebreakers and motors is also possible. **It was a deliberate decision to allow use of all functions with all types of generators, consumers etc[1].** Any protection function may be activated and deactivated individually, actions linked to a protection function may be defined by parameter (e.g. breaker trip, engine stop, de-excitation)!

The device is fully suitable for all kind of electrical units, but it should not be forgotten that the GPM500 is primarily designed for generators and several functions, indications and text-elements may therefore be “generator-like”!

Later on it was decided to add a device for protection of Diesel engines, which is quite similar in its design (Diesel Protection Module DPM500).

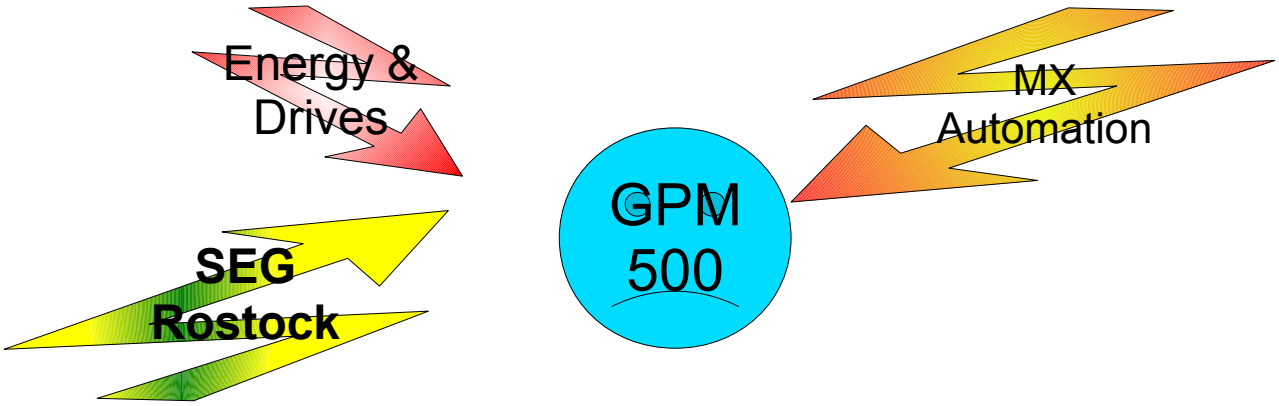
1.3 Requirements GPM500

There was no real requirements specification at the beginning, in spite of a longer discussion with all concerned departments. The original intention was to get a replacement for the aged GMM10 and its sisters. So it was intended to have a protection device and a decentralized power management unit combined in the same device as it was within the GMM. During the development phase interests of involved departments began to diverge:

- Automation department wishes a pure protection unit and plans to build a decentralized power management unit in addition.
- Energy & Drives (E&D) development planned to include a power management (PMS) after creating the protection device and prepared it
- E&D management stepped back with integrating a power management (PMS) after Automation management claimed that as automation business
- Daughter company SEG intervened, claiming the GPM500 PMS as crucial for their business
- In the meanwhile a cruise-vessel-project forced implementation of synchronization and load-sharing services for tiebreakers, so the foundation for PMS was laid anyway

1 It may be possible, to use an asymmetry protection with transformers or to synchronize at transformer breakers. Blackout-start mechanism may for example used for supply transformers as well as for generators.

- PMS was included for the standard GPM



Regarding this history we must not wonder that there is no standard solution inside SAM for PMS. Four main solutions are often implemented:

- GPM as pure protection device (only China and Korea)
- GPM protects and synchronizes, load-sharing and load-dependent start & stop by external PMS
- GPM does all these functions without load-dependent start & stop
- GPM as protection device and PMS

A rare solution is using GPM500 as PMS without protection functions (or only the expensive protection functions...)

The reader may imagine, that there are even some more variants, e.g. may the blackout-start made by GPM500, while load-dependent start and stop is left to an external PMS.

Two years after introduction of the GPM the Diesel Protection Module DPM500 was added! Market demanded an independent unit for diesel protection and monitoring and so the DPM was developed!

1.4 Standard

Building a software-standard which may cover all needs is a hard business. Many people are challenging the standard by presenting very specific requirements to cover needs of their respective customers.

Nevertheless a standard software is maintained:

271.001020.**xy** for the main processing unit ZKG500

271.001100.xy for the NEW main processing unit ZKG501

271.001301.**x** for the data acquisition unit SLE500

271.001310.**x** for the NEW data acquisition unit SLE501

271.001211.**xy** for the touch panel BAT500

If an improved software is delivered, the version index (**x, xy**) is incremented. Version numbering follows the following scheme:

271.001020(.00)->271.001020.A0->..->271.001020.A9->271.001020.B0 etc

It is important to maintain a standard even if customer-specific versions have to be created. Standards are at least bearing the experience of many years of development and commissioning phases of many vessels. So it is much better to derive specific solutions from a standard than deriving specific solutions from earlier specific solutions.

1.5 Software Identification

Not all projects are covered by standard software, so derivatives (variants) are programmed and identified by own numbers:

Module	SW-number	Description
ZKG500	271.0010__.__	
	271.001008	Deprecated, CANopen
	271.001020	Standard, CANopen HMI
ZKG501	271.0011__.__	New CPU to be introduced 08/2011
	271.001100	Standard
BAT500	271.0012__.__	
	271.001211	Touch-panel for GPM
	271.001212	Touch-panel for GPM&DPM
	271.001213	Touch-panel for DPM
	271.001221	Touch-panel for GPM (without Start-button & Stop-button)
	271.001224	Touch-panel for GPM (ID $03) and “TAKE/RELEASE”-buttons
	271.001225	Touch-panel for GPM (ID $04) and “TAKE/RELEASE”-buttons
SLE500	271.0013__._	
	271.001304	Standard
SLE501	271.001310	Standard
ZKG500 / DPM	271.0014__.__	
	271.001400	Standard

Remark:

Versions of one software are identified by different indexes 271.001???.**xy**, while variants are identified by SW-numbers 271.001**xyz**.??. Versions are generally compatible and versions with higher index are thought to replace versions with lower indexes without loss of functionality!

In folder-names dots '.' may be replaced by underscores '_' in the future to avoid misinterpretation of dots by programming tools.

1.6 Modularity

The GPM500 is designed modular as well regarding the software as the hardware. It may be modified to fit special requirements by trained designers (not developers). It was a clearly stated objective of GPM500´s development to allow the selection of the common patterns of protection device behavior via parameter (and not by programming).

All protection functions own in addition to the common parameters like threshold and delay a function parameter (Function code). This parameter defines the reaction of the device in case of triggering a protection function (refer to 4.1.6.1).

The GPM500 is designed for operation with an external Human Machine Interface HMI, which is an touch panel type BAT500. So the software supports the page structure of these type of panels.

1.7 Modularity by Subnet Number

Protection tasks are carried out by the devices without any cooperation. Management and control tasks require some interactions between GPM500. Therefore GPM500 have to determine, how they are working together. The fact of working together is expressed by having a common subnet number. Subnet numbers are a very important part of the PMS concept. Subnet numbers will be calculated dynamically depending on breaker positions of bus ties.

Subnet: A subnet is a piece of the network divided from other subnets by open breakers. The subnet owns an unique **subnet number**, which is calculated dynamically!

Busbar is any part of the network, which may be separated by switches, breakers, contactors[1]. Parts of a logical busbar may be isolated by transformers. Busbar-numbers are static, but may be selected via digital inputs[2]. The assignment of busbar-numbers describes the static structure and topology of the network!

UNIT 2 GPM500 Structure

2.1 Hardware

GPM500 Hardware is designed modular, the modules are to be snapped on DIN-rails, the electrical connection of modules is established automatically by putting them together. This connection is called the module bus. The internal communication of modules is effected by CAN (internal name CAN0), as long as modules are equipped with controllers

1 A transformer with primary and secondary breaker is also a “busbar” in a topological sense!
2 Not needed, if all breakers are equipped with individual GPM!

or processors.

There are two types of modules:

- Digital modules: The module bus contains two CAN-buses (CAN0 & CAN4) and different supply voltages. Digital modules have their male bus-connectors on the left side.
- Analogue modules: The module bus carries 9 analogue signals and supply voltages. Analogue modules bear their male connectors on their right side.

Both types of module buses may not be mingled (and cannot because of coding), only the Signal Evaluation Module SLE500 may be connected to both buses. Therefore SLE500 must placed between both module buses and bear male bus connectors on both sides!

It is very important to activate the appropriate termination resistors in the modules:

- CAN0 is terminated in the NEG50x (left bus-ternination) and inside the SLE50x (right termination)
- CAN4 is terminated inside the touch-panel plug and inside the SLE50x

Termination resistors are activated by jumpers. The appropriate setting is noted in a jumper-list, which should be provided by the design-department.

2.1.1 Power supply NEG5xx

The GPM500 is supplied by the NEG modules. The modules NEG5xx are intended to be fed by two different supplies:

1. DC 24 V -Automation voltage
2. AC 19 V from special transformer, connected to generator voltage (if a second 24 V-DC-source is used instead, make sure to connect terminals 5, 6 & 7 together to +24 V to reduce load for the internal fuses)



The latter voltage allows continued operation of generator protection and PMS in case of failure of the automation battery. An internal ultra capacitor maintains supply of the GPM500 for about one second to safeguard short-circuit protection.

Both voltages are monitored by the internal CAN-controllers. Missing supply voltages may lead to an alarm. The NEG modules provide 24 VDC (backed-up and filtered) and 5 VDC (via DC/DC-converter) to the other modules.

Three modules are named NEG:

•**NEG500**: 5 VDC output (DC/DC-converter) is restricted to 1 A

•**NEG501**: no DC/DC-converter (only 24 V supply), 5VDC generated by ...

•**NEG510 (“THE BOOSTER”)**, which is capable of delivering 2 A using an increased DC/DC-converter.

Standard GPM use the NEG501/510 couple, very small applications may use the NEG500 to save space.

NEG500 and 501 are equipped with a CAN-controller which monitors both external supply voltages while NEG510 is the only module without CAN-connection on the digital module's side. NEG 500 & 501 contain fuses which may cause loss of a supply-voltage!

2.1.2 Central Module ZKG500 / ZK501

The central module implements most of the management and protection functions of the GPM500. The ZKG500 links the different field-bus systems (refer to 5.1.1 ff.), there is no direct traffic between other modules[1]. The ZKG500 may be programmed using a Graphic Program Editor (GPE[2]) and may be adapted to special tasks. Its EEPROM stores parameters for protection and management functions. The ZKG500 owns a RS232-like service port (TTL level, adapter required) for loading programs and parameters and monitoring internal functions via the GPE[3].

A watchdog is implemented to make sure that digital outputs (DIO500/GOV500) are brought in safe position in case of a processor failure.

The ZKG500 uses a specific digital output to pass the switch-on command to the SLE500. (ZKG500:16 -> SLE500:32)!!

2.1.3 Governor Control Module GOV500

The GOV module contains two digital outputs specially designed to control a variety of governors:

- Governor with DC-motor, control via two wires by changing polarity
- Governor with AC-motor, three wires (common, increase, decrease)
- Electronic diesel control, three wires (common +24 V from diesel control, increase, decrease)

Two analog outputs (0-20 mA, -10 - +10 V)

2.1.4 Digital Input & Output Module DIO500

8 Digital Inputs, 4 Digital Outputs. DO can be jumpered as normally open (standard) or normally closed. DI may be paired by jumpers to form a fail-safe loop (DI 1&5, 2&6, 3&7, 4&8). Normally (standard jumper setting) all output relays are supplied via ZKG's watchdog-relay, so they will open in case of a ZKG-failure!

2.1.5 Signal Evaluation Module SLE500

2.1.5.1 Current Channels

The GPM uses two types of current channels:

- Measurement channels acquire currents up to 2 A_{rms}
- Protection channels acquire currents up to 8 A_{rms}

SLE500 is designed for direct connection of current transformers with 1 A rated secondary current.

2.1.5.2 Voltage Channels

TRV500 voltage channels are capable of measuring up to 600 V_{rms}, 0.707 ($5A7E) in the internal representation. The peak voltage may be up to 848,5 V (1.0 =$7FFF in the

1 A direct connection between display BAT500 and SLE500 is nevertheless possible, that will be used for diagnostic purposes in the future!
2 according to DIN/ISO-Standard
3 The GPE is not just an editor but may be switched in an online mode to visualize analog and digital data.

internal representation)[1].

2.1.5.3 Analogue channels

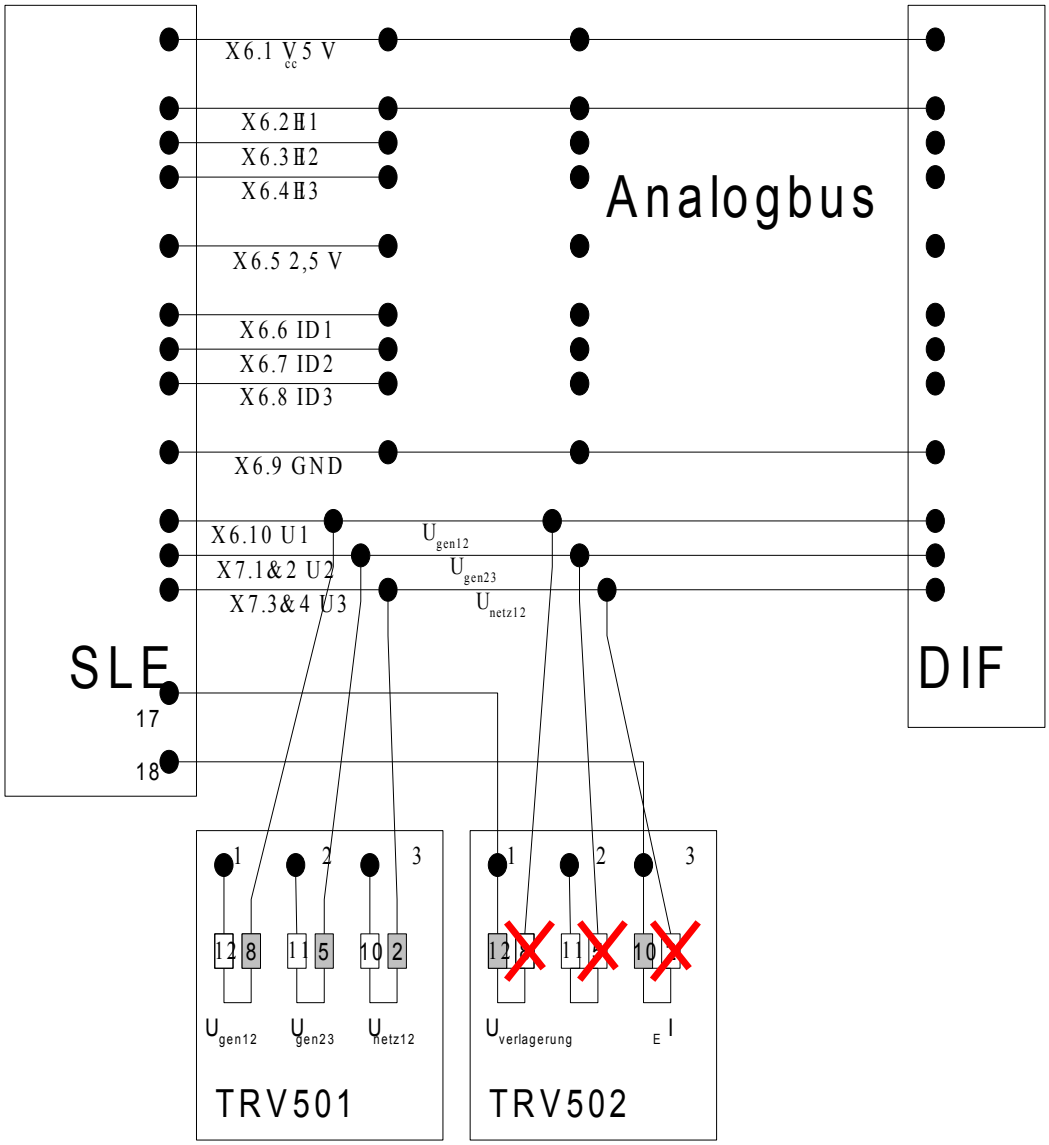
Three currents are measured directly by the SLE500, other signals are conditioned by transducer modules TRV500 / current transformer module DIF500. Both modules are connected to the SLE500 either via analogue module bus or via external wiring. SLE500´s processor is capable of measuring up to 16 analogue signals.

Channel	***Measured value***	***Name***	***external port SLE500***	***external port TRV500 Output***	***external port TRV500 / DIF500 input***
0	Generator voltage V_{gen12}	U1	X6.10	1 X6.10	TRV:13,16 **Type 500** **Type 501** **Type 502**
1	Generator voltage V_{gen23} < 600 V Type 500 < 200 V Type 501/502	U2	X7.1&2	2 X7.1&2	TRV:9,12 **Type 500** **Type 501** **Type 502**
2	Mains voltage V_{netz12}	U3	X7.3&4	3 X7.3&4	TRV:5,8 **Type 500,** **Type 501**
3	Displacement voltage $U_{10}+U_{20}+U_{30}$ (Ground voltage) **only via external connection**	US1	17	1 ~~**X7.1&2**~~	TRV:13,16 **Type 502** **Type 504**
4	zero-system current transformer I_E (Ground current) **only via external connection**	US2	18	3 ~~**X7.3&4**~~	TRV:5,8 **Type 502** **Type 504**

1 $848,5\ V = 2^{0,5} \cdot 600\ V$

Channel	***Measured value***	***Name***	***external port SLE500***	***external port TRV500 Output***	***external port TRV500 / DIF500 input***
5	Current I_1 for short-circuit protection and differential protection <8,0A	IS1	25,26	**SLE-intern** (transformer primary or generator starpoint side)	
6	Current I_2 for short-circuit protection and differential protection <8,0A	IS2	27,28		
7	Current I_3 for short-circuit protection and differential protection <8,0A	IS3	11,12		
8	Current I_1 high resolution (Measurement) <2,0A	IM1	25,26		
9	Current I_2 high resolution (Measurement) <2,0A	IM2	27,28		
10	Currents secondary coils 2 <8,0A	IE1	X6.2	X6.2	DIF:13,14
11		IE2	X6.3	X6.3	DIF:15,16
12		IE3	X6.4	X6.4	DIF:9,10
13	Currents secondary coils 1 <8,0A	ID1	X6.6	X6.6	DIF:1,2
14	(or generator switchboard side)	ID2	X6.7	X6.7	DIF:3,4
15		ID3	X6.8	X6.8	DIF:5,6

Important! *Analogue bus channels (X6, X7 in module drawings) should be connected to only one transformer/transducer! Additional TRV500 may therefore only be connected via external wiring! If only a TRV502 is connected,* **X6.10 und X7.1&2** *may be used, the current channel must be connected by external wiring.*



The next diagram shows wiring of a medium voltage installation with transducer module TRV501 (delta voltages) together with an TRV502 for acquisition of displacement voltage and earthfault current!

2.1.5.4 Independent Short-circuit Protection & Lockout-relay (ANSI 86)

Measured values are digitized in the signal acquisition module SLE500. The module provides instantaneous overcurrent (short-circuit) protection (ANSI 50) and differential protection (ANSI 87 T/G). An processor-independent (and supply-independent) tripping mechanism is integrated in the module. This mechanism needs no auxiliary voltage. It trips with currents of 2.5 A with a delay of 250 ms[1] using a memory relay. This relay would be switched in the TRIPPED-position and remains permanently in that position (red LED

1 Adaptable!

on top of the module stays ON, after recovery of the GPM the display shows “Hardware trip” [1]alarm!).

The same relay is used by the processor in case of trip or disconnection. The relay can be used with shunt-trip coils and undervoltage-coils (selectable by jumpers).

2.1.5.5 Synchronization and Closing

The ZKG500 as well as the SLE500 are checking independently, whether mains and generator voltage are synchronized. Both modules must generate the CLOSING command at the same time, both digital signals are needed to activate the closing relay of the SLE500 (hardwired AND). CLOSING command of ZKG500 will be transmitted to the SLE500 via external wiring (ZKG500:16 -> SLE500:32).

2.1.5.6 Life sign

The SLE500 provides a digital output () operated by a watchdog device. The watchdog signal covers also the ZKG operation, so only one watchdog signal has to be wired.

2.1.6 Transducer Module TRV50x

Proper selection and configuration of the TRV50x is very important for the function of the GPM500. Transducer modules are capable of transferring three voltages or currents (mains potential) into signal voltages on processor level.

Up to now four different types of TRV50x are at designers disposal and must be defined by parameter 188 of the GPM500.

Code (dez)	***Code (hex)***	***Type***	***Description***
0	0	TRV500	Three voltage inputs 0-600 V_{rms} (848,5 V_s) TRV500:13,16 : V_{gen12} TRV500:9,12 : V_{gen23} TRV500:8,5 : $V_{mains12}$ *Direct connection to generator/mains voltages!*

1The “Hardware trip”-alarm is often criticized by users and there are sometimes requests to remove that signal from the alarm page. But there must be an indication, if the memory-relay inside the SLE50x is permanently in the OFF-position!

Code (dez)	Code (hex)	Type	Description
1	1	TRV501	Three voltage inputs 0-200 V_{rms}: TRV501:13,16 : V_{gen12} TRV501:9,12 : V_{gen23} TRV501:8,5 : $V_{mains12}$ *Medium voltage plants, 100 V ≡ rated voltage*
2	2	TRV502	Two voltage inputs 0-200V_{eff} TRV502:13,16 : $V_{mains12}$ / V_{disp} TRV502:9,12 : $V_{mains23}$ Current input 1A TRV502:8,5 : I_{earth}
4	4	TRV504	Two voltage inputs 0-200V_{eff} TRV504:13,16 : $V_{mains12}$ / V_{disp} TRV504:9,12 : $V_{mains23}$ Current input 0.0015 A TRV504:8,5 : I_{earth}

Type TRV500 is designed for direct connection to low voltage networks with rated voltage of 400/440 V, while TRV501 is used for medium voltage plants, where voltage is acquired via voltage transformers with a standardized rated voltage of 100 V. TRV502 and 504 are designed for medium voltage networks using one channel for earthfault detection via ZCT. TRV504 contains an internal amplifier and must be used together with a special SLE-software!

Only one TRV should be connected to the analog module bus to avoid interference.

2.1.7 Differential Protection Extension DIF500

2.1.7.1 Connection

The DIF500 is always connected via analog module bus. Differential protection will not trip, if secondary currents of one phase are flowing in the same direction from L (S2) to K(S1). Phase shifts and current transformer ratio may taken into account by adjusting Reg 177 to Reg 180.

2.1.7.2 Commissioning

One special remark regarding commissioning of GPM500 for protection of transformers: Inrush of transformers may cause trip by protection functions ANSI 50 (Short circuit,

instantaneous overcurrent) and ANSI 87 (Differential protection). Actual level of second harmonic in the transformers or generators current is displayed on the BAT500s differential protection page. Transformer should be connected several times with Differential protection deactivated to determine an appropriate setting.

2.1.7.3 DIF500 as Input for Load-monitor

A consumer, which will take the requested power immediately after connection, needs no power feedback. Power is either requested (signaled by contact) or is actually needed (then measured by the generators GPM500).

Other consumers may cause problems: If power is not needed immediately after connection (e.g. running idle), the requested spare power is released, but actual load is not increased appropriate. In this case the PMS has free spare power which may be automatically reduced either by new consumers or for by stopping generator sets. Later the requested spare power of the consumer may be needed suddenly, consequential the network may break down.

To avoid this effect, actual power consumption must be measured or calculated. If knowing the actual power consumption of the consumer, the GPM500 can release just that amount of requested spare power, which is not longer needed because it became part of the generators actual power.

Actual consumer load is acquired using the unused current channels of the DIF500, which are not used for differential protection. Currents are measured single-phase, consumer voltage is known by the GPM500, because it must be identical to mains voltage.

Consumer 1 uses the last current channel, consumer 2 the next to last etc. Channel assignment according to the following scheme (Base= name of the first DIO500 for consumer control, e.g. DIO500#3):

Nr.	***Request***	***Feedback***	***Lamp Indication***	***Consumer Release***	***Current acquisition***
	DIO500#x:y	DIO500#x:y	DIO500#x:y	DIO500#x:y	DIF500
1	Base:9 (DI 1)	Base:10 (DI 2)	Base:5,6	Base:7,8	:9,10
2	Base:11	Base:12	Base:1,2	Base:3,4	:15,16
3	Base+1:9	Base+1:10	Base+1:5,6	Base+1:7,8	:13,14
4	Base+1:11	Base+1:12	Base+1:1,2	Base+1:3,4	:5,6
5	Base+2:9	Base+2:10	Base+2:5,6	Base+2:7,8	:3,4
6	Base+2:11	Base+2:12	Base+2:1,2	Base+2:3,4	:1,2

A generators GPM may control three consumers with current acquisition (if GPM500 includes differential protection), GPM500 for tiebreakers, motors or transformers without differential protection may control 6 consumers with current acquisition.

Important: *Some drawings and documents (copy-paste error) are mixing up indication and release outputs. DO1 & DO3 are for indication while DO2 and DO4 are closing the consumer breaker.*

2.1.8 Introduction Touch-Panel BAT500 (eTop05)

2.1.8.1 Structure

The GPM500 uses an industrial type touch-panel as interface to the operator. It is slightly modified to meet ship-specific requirements. The interface is page-orientated, pages are assigned to certain functions of the system. In addition to a clear presentation of operational states and acquired data aids for check and commissioning are integrated. Parameters of the GPM500 may be altered using the panel. The parameters are protected by password[1].

BAT500 contains standard firmware supplied by the manufacturer and a graphical application, which could be build by a graphical design tool. The application is stored on a memory card, which may be changed to load a new application.

2.1.8.2 "Programming" by Designer 6.x

The manufacturer of the BAT500 supplies a design tool, which allows building a MMI in a few steps. Any (animated) object on the screen is linked to cells in the BAT500´s internal memory and most objects are linked to GPM500s memory too. Some objects are invisible, e.g. the alarm buzzer!

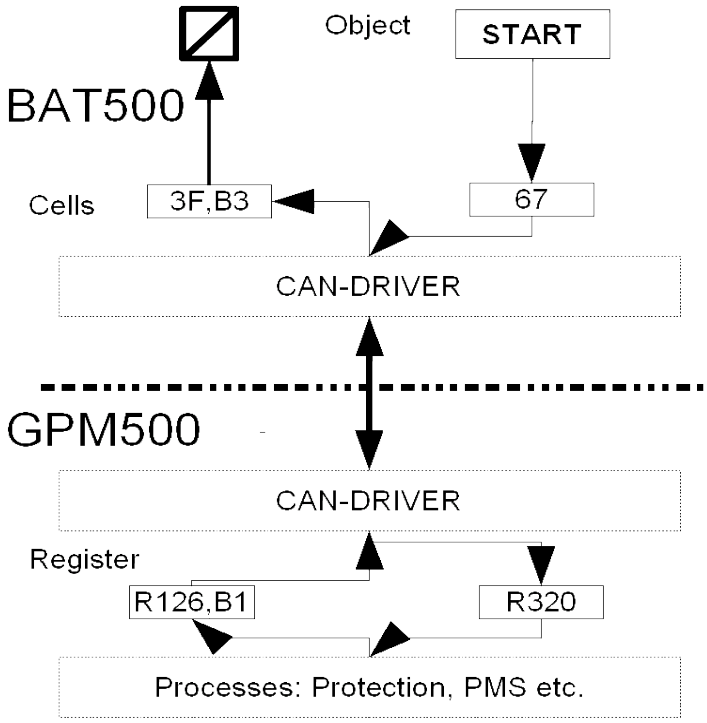


Diagram 2.1.1GPM500/BAT500 data model

1 Protection against accidental changes!

The contents of BAT500 cells (4 byte) are copied into Registers of the ZKG500 or vice versa. So process data of the GPM can visualized on the BAT500s screen and operators actions on the panel may influence the GPM500s processes. The look of the respective object may be changed without influencing the process. E.g. renaming or moving of a touchbutton will not have any influence regarding the processes behavior.

2.1.8.3 Overview

The touch panel is page-orientated, pages are build up according to a common scheme: A navigation bar is displayed at the bottom of every page, it allows changing of pages and jump to special pages. The touch panel BAT500 provides different types of pages:

Page	***Type, Content***	***Description***
1	Process data	Overview, Position of breakers and contactors
2		Measured values
3	Alarm page	Alarm page selection
4		
5		
6	Panel operation	Brightness, Password, language selection
7	Menu	Navigation
8	Parameter	Generator (Device No.), busbar, device type (GEN/MOT/TRANSF), switch-on release, blackout start
9		Rated values & current transformer ratio
10		Rated values & transformer ratio
11		Load distribution, frequency control
12		Instantaneous overcurrent (short-circuit)(ANSI 50)
13		Differential protection (87)
14		Stator protection (50)
15		Overcurrent, definite time (51)
16		Overcurrent, inverse time (51)
17		Unbalanced current (46)
18		Undervoltage (27)
19		Overvoltage (59)
20		Underfrequency (81L)
21		Overfrequency (81H)
22		Reverse Power (32)
23		Underload (37)
24		Field failure / Underexcitation (40)
25		Preferential trip
26		Synchron-Test (25)

Page	Type, Content	Description
27		Start-, Stop-, Enginefailure
28		Internal Failures 1: Undervoltage supply voltages (27s) and CAN-error
29		Internal Failures 2: Breaker failure & Checksums
30		Internal Failures 3: Governor alarm, Voltage acq. alarm
31	Parameter	Earthfault (51N)
32		Voltage displacement, ground-voltage (59N)
33		Powermanagement: Loadmonitor (refer to 9.1.1.1)
34		Powermanagement: consumer data (refer to 9.1.1.2)
35	Alarm	CAN 4 failure (not used)
36	Parameter	Voltage correction
37	START	Confirm START command
38	STOP	Confirm STOP command
39	Diagnostic “St”	Start logic
40	Diagnostic “HW”	Hardware (DIO function, CAN function)
41	Panel selection	Selection of active Panel
42	DPM parameter	If available ...

2.1.8.4 Page Design

The pages header contains a headline, displays the actual parameter check-sum and a sign of life signaling that panel data is permanently refreshed by the GPM500. Furthermore the actual panel status (ACTIVE/PASSIVE) is indicated[1]. A navigation bar is placed at the bottom of the page and allows navigation commands “Step forward”, “Step backward”, “Go to MENU page” and “Go to ALARM page”[2]. The navigation bar is flashing if alarms are unacknowledged.

The symbol  is shown as long the alarm page is empty while  is indicated as long as alarms are displayed on the alarm page.

2.2 Digital Inputs and Outputs

IO should be described using the following table!

1 Panels may be PASSIVE when there are more panels (up to 4). Only one panel will be ACTIVE, except interlock is suspended by setting Par. 154, Bit 15!

2 “Go to MENU page” is replaced by “HOME (page1)” on the menu page itself

- “Go to ALARM page” is replaced by “ACK”(knowledge) on the alarm page itself.
- “Go to MENU page” is replaced by “BACK”(to the former page) on the alarm page.

2.2.1 Basic I/O

Module	PIN	Channel	Variable (Name)	Function
ZK500	01,05	Watchdog		-forbidden- EMC!
	16	ZU_FREI		Clos. Release ->SLE500:32
	09,12	AI1	EW1	Load simulation (Use isolation amplifier!)
	10,12	AI2	EW2	Power limitation (Use isolation amplifier!)
	11,12	AI3	EW3	-spare- (Use isolation amplifier!)
GOV500	10,9	DI1	EKAZI2	Select Current I2
	12,11	DI2	EKAZI3	Select Current I3
	1,2,3	DO1	AKHOCH	Governor: INCREASE speed (UP)
	1,2,3	DO2	AKTIEF	Governor: DECREASE speed (DOWN)
	14,13	AO1	AWPWIRK	actual Power (0-10 V)
	16,15	AO2	AWIEFF	Current (0-20 mA)
DIO500#1	9	DI1	EKABS	Stop/Disconnect *Automatic mode: Starts stop sequence! Unloading, disconnection and stop!* *Manual mode:* *Confirms opening of breaker, when opened by external system!*
	10	DI2	EKGEI	Feedback – Breaker CLOSED
	11	DI3	EKSTART	Start/Connect *Automatic mode: Starts start sequence (Starting, synchronizing and loading)* *Manual mode:* *Starts diesel, no synchronization/ no blackout-connection*
	12	DI4	EKDRBUKL	Linebreak – Emergency STOP
	13	DI5	EKATM	Automatic *Mode selection only by this input! No mode selection by IAMCS, touchpanel etc.*
	14	DI6	EKQUT	Acknowledge alarms
	15	DI7	EKREADY	Ready for START *Must be present for start in Automatic mode, not needed after beginning the start sequence!*
	16	DI8	EKUNKLAR	Emergency Stop / Enginefailure *Linebreak monitored via DI4!*
	5,6	DO1	AKSTART	Diesel Start
	7,8	DO2	AKSTOP	Diesel Stop
	1,2	DO3	AKSAGL	TRIPPED (just information)
	3,4	DO4	SAMMELALARM	Common alarm (closed w/o alarm)
DIO500#2	9	DI1	EKTENSION	Breaker closing spring is charged *ready to close – DG may be started, but can´t be connected if not active*
	10	DI2	EKTRENN	Breaker is in ISOLATED position

Module	PIN	Channel	Variable (Name)	Function
	11	DI3	ENITRENN	Breaker is in SERVICE position
	12	DI4	EKERDER	EARTHED
	13	DI5	ENIERDER	NOT EARTHED
	14	DI6	ENGEI	Breaker is OPEN
	15	DI7	ENISERDER	Busbar not earthed *Must be set to enable Start/Connection as well as synchronization / blackout - connection in Automatic mode!*
	16	DI8	EKBLACKOUT	Busbar has Blackout *Signals, that all feeding breakers are open! Must be permanently set with consumers! Must be active with tiebreakers, if at least one side has blackout!*
	5,6	DO1	AKDEEX	Deexcitation (just for deexcitation in case of faults, shaft generators may be excited using start and de-excited using stop outputs [DIO500#1: DO1/2])
	7,8	DO2	AKUNW1	Preferential Trip 1
	1,2	DO3	AKUNW2	Preferential Trip 2
	3,4	DO4	AKUNW3	Preferential Trip 3
DIO500#3 (Preferen-tial TRIP, DIO-Code 8_{10})	9	DI1		
	10	DI2		
	11	DI3		
	12	DI4	980;3	Emergency Mode (Emergency-& Harbor-generator)
	13	DI5		Only DIO500#3: Synchronization to third busbar
	14	DI6		Only DIO500#3: Synchronization to second busbar
	15	DI7		Only DIO500#3: Connected with third busbar
	16	DI8		Only DIO500#3: Connected with second busbar
	5,6	DO1		Preferential Trip 4
	7,8	DO2		Preferential Trip 5
	1,2	DO3		Emergency Mode (Emergency-& Harbor-generator)
	3,4	DO4		SYNC-release (Lockout-relay)
DIO500#3 or DIO500#4 (PMS Operation modes, DIO-Code 7_{10})	9	DI1	981;0	No DG Start (by PMS)
	10	DI2		No DG Stop (by PMS)
	11	DI3		Request spare generator (Manoevre-mode)
	12	DI4		-- spare --
	13	DI5		Only DIO500#3: Synchronization to third busbar
	14	DI6		Only DIO500#3: Synchronization to second busbar
	15	DI7		Only DIO500#3:

Module	PIN	Channel	Variable (Name)	Function
				Connected with third busbar
	16	DI8		Only DIO500#3: Connected with second busbar
	5,6	DO1		No DG Start (by PMS)
	7,8	DO2		No DG Stop (by PMS)
	1,2	DO3		Request spare generator
	3,4	DO4		SYNC-release (also Lockout-relay, see DIO before)
DIO500#3 to DIO500#5 (PMS, Consumer 1 & 2 Control, DIO-Code 1_{10})	9	DI1	982;0	Request Consumer 1
	10	DI2	982;1	Consumer 1 connected
	11	DI3	982;2	Request Consumer 2
	12	DI4	982;3	Consumer 2 connected
	13	DI5		Only DIO500#3: Synchronization to third busbar
	14	DI6		Only DIO500#3: Synchronization to second busbar
	15	DI7		Only DIO500#3: Connected with third busbar
	16	DI8		Only DIO500#3: Connected with second busbar
	5,6	DO1	992;8	Consumer 1: Status indication
	7,8	DO2	992;9	Consumer 1: Connect
	1,2	DO3	992;10	Consumer 2: Status indication
	3,4	DO4	992;11	Consumer 2: Connect
DIO500#4 to DIO500#6 (PMS Consumer 3 & 4 Control, DIO-Code 2_{10})	9	DI1		Request Consumer 3
	10	DI2		Consumer 3 connected
	11	DI3		Request Consumer 4
	12	DI4		Consumer 4 connected
	13	DI5		
	14	DI6		
	15	DI7		
	16	DI8		
	5,6	DO1	993,8	Consumer 3: Status indication
	7,8	DO2	993,9	Consumer 3: Connect
	1,2	DO3	993,10	Consumer 4: Status indication
	3,4	DO4	993,11	Consumer 4: Connect
DIO500#5 to DIO500#7 (PMS Consumer 5 & 6 Control, DIO-Code 3_{10})	9	DI1		Request Consumer 5
	10			Consumer 5 connected
	11			Request Consumer 6
	12			Consumer 6 connected
	13			
	14			
	15			
	16	DI8		
	5,6	DO1		Consumer 5: Status indication
	7,8			Consumer 5: Connect
	1,2			Consumer 6: Status indication
	3,4	DO4		Consumer 6: Connect

For special tasks up to two so-called Special Function DIO may be created by modification of the standard software (SDIO1 / SDIO2 !) with DIO-Codes 4_{10} & 5_{10}!

Remark: No release contact provided for manual operation, manual operation should not be influenced/blocked by the GPM500!

2.2.2 Manual/Automatic

The GPM500 uses two operation modes, the operator may force AUTO mode by setting DIO500#1: 13(DI5). **Mode is selected for any individual generator.** Operation mode is only influenced by this DI. The following differences can be found:

Operation Mode	
Manual	***Automatic***
No synchronization!	Synchronization if Par. 147, Bit 8 or 9 set!
No Blackout-Start	BO-Start, if Par.189, Bit 0 set!
No load sharing!	Load sharing!
Not included in Power Management, generator set will not be started by PMS and spare power will not be included in calculation, if connected. [1]	Internal PMS may be enabled by setting Par.189, Bit 1! Generator set will be started and stopped load-dependent.
DIO500#1:9 (DI11)(**START**) starts generator set without synchronizing later!	DIO500#1:9 (DI11)(**START**) starts generator set
DIO500#1:9 (DI1)(**STOP**) only used to confirm breaker opening if using an independent path. *To avoid breaker failure alarm!*	DIO500#1:9 (DI1) initiates disconnection with prior unloading! It is checked, whether spare power is sufficient. *Often the breaker is opened directly using the same pushbutton, in that case prior unloading has no effect!*
Touchbutton “Start” starts generator set without synchronizing!	Touchbutton “Start” starts generator set and starts synchronization!
Touchbutton “Stop” disconnects and stops generator set without checking spare power!	Touchbutton “Stop” disconnects and stops generator set with prior check of spare power!
No cooling-down! Diesel remains running until being stopped manually! (e.g. touchbutton “Stop”!)	Diesel kept running for cooling down after disconnection! Stops automatically after cooling-down delay is finished!
--	Time for Start, Stop, Synchronization will be monitored, if respective alarms are activated!

2.2.3 Switch-on Path / Switch-off Path

A circuit breaker must be switched manually using an independent path. The manual mode is not to be locked by the protection device (if no trip alarm is blocking), if interlocks

1 Switching to MAN may cause start of an additional generator, because subnet lacks spare power!

had to be made, they must be included in the manual path (e.g check synchronizer, voltage relay, blackout-relay). The protection device GPM500 blocks breakers just using the undervoltage coil controlled by an memory relay on board the SLE500[1].

An voltage relay fed by the generator voltage must provide a contact in the manual connection path to prevent connection of generators without generator voltage [2].

Normally breakers will be opened using their undervoltage coil. In addition to the GPM500s relay a NC-contact of a pushbutton (STOP) is used to deenergize the undervoltage coil. An NO contact is used to inform the GPM.

The NC contact may be bypassed in position AUTO of the mode selector switch to avoid accidental disconnection.

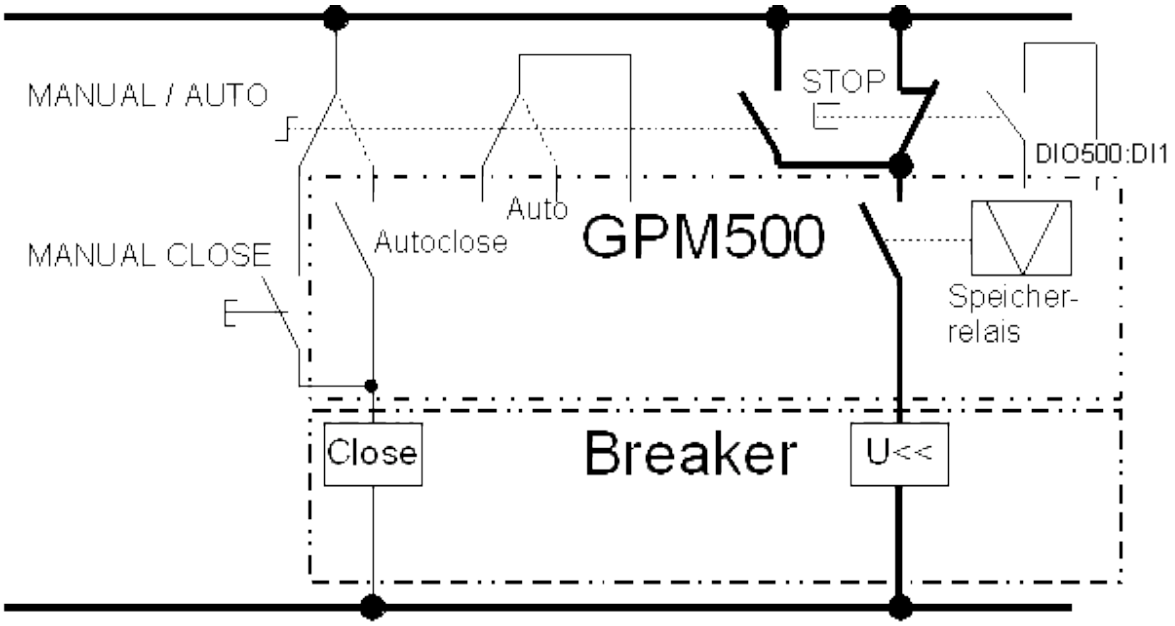


Diagram 2.2.1: Connection of breaker coils. The GPM500 uses the so-called "Speicher-Relais" for lock-out!

2.2.4 Digital Inputs and Outputs PMS

The GPM500 needs digital inputs and outputs for the load-monitor functions. Not all functions will be needed for all devices. We have to distinguish two types of digital inputs and digital outputs (DI and DO):

1. DI and DO for selection of operation mode
2. DI and DO for control of particular consumers

Mode selection must not be possible at any device, because any mode selection influences the whole subnet. The mode selection inputs of different GPM500 are connected via a distributed OR: If any mode selection DI is set, the appropriate mode is selected for the subnet[3]. If maneuver mode is selected at one device, all devices assume

1 Only if breakers are prevented from closing in case of an open undervoltage coil circuit.
2In contrast with GMM10 GPM500 provides no switch-on release for manual operation!

3 The GPM500´s load monitor may be distributed to all GPM500 of the network. So a simple mechanism had to be found to cope with mode selections made at different places.

maneuver mode. DI for mode selection therefore must be permanently set.

A separate DIO is to be used to select and display operation modes. If such a DIO500 should be used, it must be defined per parameter. If this parameter is set, consumer-related DI and DO are shifted to DIO500 with higher ordinal numbers (#x). This is done the same way for additional outputs for differential trip:

No	**DIO500#1**	**DIO500#2**	**DIO500#3**	**DIO500#4**	**DIO500#5**	**DIO500#6**	**DIO500#7**
1	Standard contacts		Consumer 1&2	Consumer 3&4	Consumer 5&6	----------	
2	Standard contacts		Operation mode	Consumer 1&2	Consumer 3&4	Consumer 5&6	
3	Standard contacts		Preferen-tial trip extension	Consumer 1&2	Consumer 3&4	Consumer 5&6	
4	Standard contacts		Preferen-tial-trip extension	Operation mode	Consumer 1&2	Consumer 3&4	Consumer 5&6

DIO500 assigned to consumers must be connected according to the following scheme:

- **Request:** (maintained-contact, DIO500#x:9 DI1 for consumers 1,3 and 5, DIO500#x:11 DI3 for consumers 2,4 and 6) commands, that the spare power defined for the respective consumer should be requested. The requested spare power may be released again by opening the contact again.
- **Feedback:** (maintained-contact, DIO500#x:10 DI2 for consumers 1,3 and 5, DIO500#x:12 DI4 for consumers 2,4 and 6) informs the GPM500, that consumer is connected. Spare power will not be requested any longer[1]! The feedback contact remains closed after connection but opens again if spare power is not sufficient any longer (sometimes used for load reduction of bow thrusters etc.)
- **Release:** Release contact allows connection of consumer if spare power is sufficient. Maintained-contact operation. (DIO500#x: 7,8 DO 2 for consumers 1,3 and 5, DIO500#x:3,4 DO 4 for consumers 2,4 and 6). **Release signal is only maintained as long as Request is pending!**
- **Lamp indication:** Another output allows visualization of the actual state of connection: ***Flashing light*** indicates a pending request, while ***steady light*** indicates a connected consumer(DIO500#x: 5,6 DO 1 for consumers 1,3 and 5, DIO500#x:1,2 DO3 for consumers 2,4 and 6). ***Rapid flashes*** that pending requests can not be served (no generators available...)

2.3 Analog Signals / Measured values

Protection devices as well as Power management units are measuring and monitoring process data and take predefined actions if process data is outside predefined ranges.

1 **Exception:** The remaining spare power will be requested even in case of feedback signal if a current transformer is used (and defined in Par.69, 71 ...) to measure the actual apparent power. (current acquisition!)

The following signals are measured in simple cases (for generators, transformers may use even less) :

- Generator voltage V_{gen12}
- Generator voltage V_{gen23}
- Busbar voltage V_{net12}
- Generator stator current I_{gen1} (1 A rated current)
- Generator stator current I_{gen2}
- Generator stator current I_{gen3}
- Generator frequency f_{gen}
- Busbar frequency f_{net}

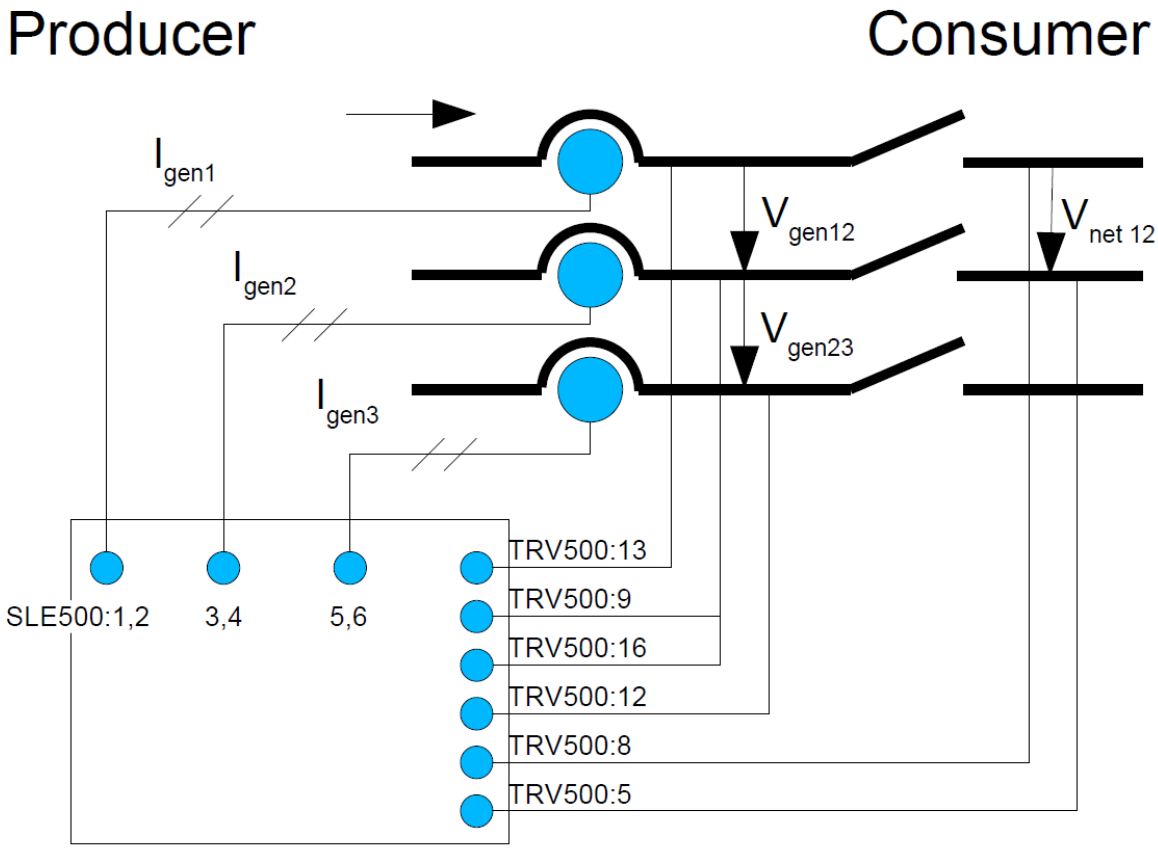


Diagram 2.3.1: Data acquisition generator (GPM500)

Additional process values are calculated by combining the signals mentioned above:

- Power P_w
- Reactive power P_r
- Apparent power P_S
- Angle (V_{gen12}, V_{net12})

- Positive-sequence voltage V_{ps}
- Levitation (v_{gen12}-v_{net12}) **Additional criterion!**

These signals are monitored by functions described in chapter 4.1.4 .

UNIT 3 DPM Structure

3.1 Hardware

As the GPM500 the DPM500 is designed modular. There are only “digital modules”, all modules are linked to the internal CAN-bus. The DPM500 uses only 4 types of modules:

- **NEG50x**
- **ZKG500**
- **SST500**
- **DIO500 (Standard 2, maximum 4)**

The SST500 is specific for DPM, the SST-board is not used in GPM. The SST has an own processor (like the SLE500) and is capable of

- measuring and monitoring the engine speed (if pick-up sensors are used)
- controlling start- and stop-valve (and monitoring the respective valve's coil)

3.2 Digital Inputs and Outputs

Module	PIN	Channel	Variable (Name)	Function
ZK500	01,05	Watchdog		-forbidden- EMC!
	16	ZU_FREI		
	09,12	AI1		-spare
	10,12	AI2		-spare-
	11,12	AI3		-spare-
SST500	9	DI1		Start-button
	10	DI2		Stop-button
	11	DI3		-spare-
	12	DI4		-spare-
	13	DI5		n > Ignition or Pick Up
	14	DI6		n > Ignition or Pick Up
	15	DI7		Emergency Stop Button
	16	DI8		Release of Start Relay
	1,2	DO1		Start (line monitoring)
	3,4	DO2		Stop (line monitoring)
	5,6	DO3		Emergency Stop (line monitoring)
	7,8	DO4		Gen. Breaker Off
DIO500#1	9	DI1		AUTOMATIC
	10	DI2		ACKNOWLEDGE
	11	DI3		BREAKER CLOSED
	12	DI4		Prelubricating Manual / external
	13	DI5		REMOTE
	14	DI6		READY
	15	DI7		BLACKOUT

Module	PIN	Channel	Variable (Name)	Function
	16	DI8		Mains recovered
	5,6	DO1		"Automatic" to GPM 500
	7,8	DO2		"Ready" to GPM 500
	1,2	DO3		Collective Alarm
	3,4	DO4		Alarm release to Monitoring System
DIO500#2	9	DI1		Emergency / Harbour Mode
	10	DI2		Line Break Input Channel DI 6
	11	DI3		Line Break Input Channel DI 7
	12	DI4		Line Break Input Channel DI 8
	13	DI5		Pre lubricating Feedback
	14	DI6		Overspeed
	15	DI7		Lubrication Oil Pressure Low
	16	DI8		Cooling Water Temperature High
	5,6	DO1		Prelubricating
	7,8	DO2		Generator Breaker ON
	1,2	DO3		DG Running
	3,4	DO4		Watchdog Relay
DIO500#3	9	DI1		Line Break Input Channel DI 5
	10	DI2		Line Break Input Channel DI 6
	11	DI3		Line Break Input Channel DI 7
	12	DI4		Line Break Input Channel DI 8
	13	DI5		Cooling Water Pressure Low
	14	DI6		Lubrication Oil Temperature High
	15	DI7		Fuel Leakage
	16	DI8		Exhaust Gas Temperature
	5,6	DO1		Governor Stop
	7,8	DO2		Alarm start
	1,2	DO3		Fuel Oil Limitation
	3,4	DO4		- spare -
DIO500#4	9	DI1		Line Break Input Channel DI 5
	10	DI2		Line Break Input Channel DI 6
	11	DI3		Line Break Input Channel DI 7
	12	DI4		Line Break Input Channel DI 8
	13	DI5		Bearing Temperature
	14	DI6		CO2
	15	DI7		Oil Mist Concentration
	16	DI8		Turbo Charger Overspeed
	5,6	DO1		- spare -
	7,8	DO2		- spare -
	1,2	DO3		- spare -
	3,4	DO4		- spare -

3.3 Analog Signals

Oops, there are none!

DAY 2
UNIT 4 Protection functions & Coordination

4.1 Definition Protection

“Main scope of protection is maintenance of supply for not affected parts of the network in case of a fault.” [1] Key words are **Selectivity** and **Discrimination**, protection devices (protection relays) should disconnect the place of fault without influencing the supply of other components.

It is a common misunderstanding regarding protection devices, that they should protect their respective motors, generators etc. So it is frequently asked in case of major faults: “The transformer is destroyed now, what about your transformer protection?”

Primary task of a protection device is protection of the network in its entirety and its ability to feed the healthy devices.

4.1.1 Network Protection

On board vessels maintenance of electrical power supply is of high importance because maneuverability is directly affected. A total loss of electrical power causes loss of propulsion and may under certain conditions lead to loss of the whole ship. This must taken in account in the protection philosophy as well as the design of protection device. (refer to description of the processor-independent overcurrent protection in chapter 2.1.5.4). Network protection often precedes protection of personal and components[1].

4.1.2 Personal Protection

Protection devices are not very important for the safety of humans onboard regarding electrical hazards. Insulation failure in TT-networks creates a short-circuit, faulty components are therefore disconnected in very short time by an instantaneous overcurrent protection device. IT-networks are designed to maintain power supply in case of an insulation failure, faulty components are not disconnected because the failure current is only small. The insulation failure is detected by a type of insulation monitoring (Ref. 4.1.5.7). Safety against electrical hazards is subordinated to security of supply (Network protection, 4.1.1).

4.1.3 Component Protection

Protection of electrical components is subordinated to protection of the whole network and therefore to the protection of the vessel. Although component protection is a important task, which may not be divided from other protection tasks, because electrical components itself may affect the ships security. (If a transformer is destroyed by overcurrent, supply of other important devices may be affected and the transformer may cause fire!)

4.1.4 Protection Functions (General Design)

This chapter shall provide an overview of protection functions implemented in the

1 Many classification societies requirements state that electrical components of the steering gear should be just cut off in case of short-circuit (Instantaneous overcurrent relay), other faults should just be alarmed. So GPM500 leaves open, whether a certain protection function should trip the circuit breaker or not, the appropriate reaction had to be defined by the design engineer(refer to 6.3).

GPM500. Their relevance to network protection, personal protection and component protection will be discussed. Protection functions are sorted according to the process data monitored (Current, voltage, frequency, [reactive] power)! The internationally standardized code (ANSI xx) is given.

Most protection functions need three parameters:

- Trigger level / threshold *(Which level must be exceeded by the measured values to get a reaction?)*
- Delay time *(How long must this level be exceeded to get an reaction?)*
- Function code *(Should we get a reaction and what type of reaction should take place?)*

Parameter numbers of the respective parameter are mentioned with the protection function. The protection functions are sorted according to the type of measured values monitored. This scheme is also used for the visualization of the parameters by the touch-panel:

4.1.5 Current-related Protection Functions

4.1.5.1 Instantaneous Overcurrent / Short-circuit (ANSI 50)

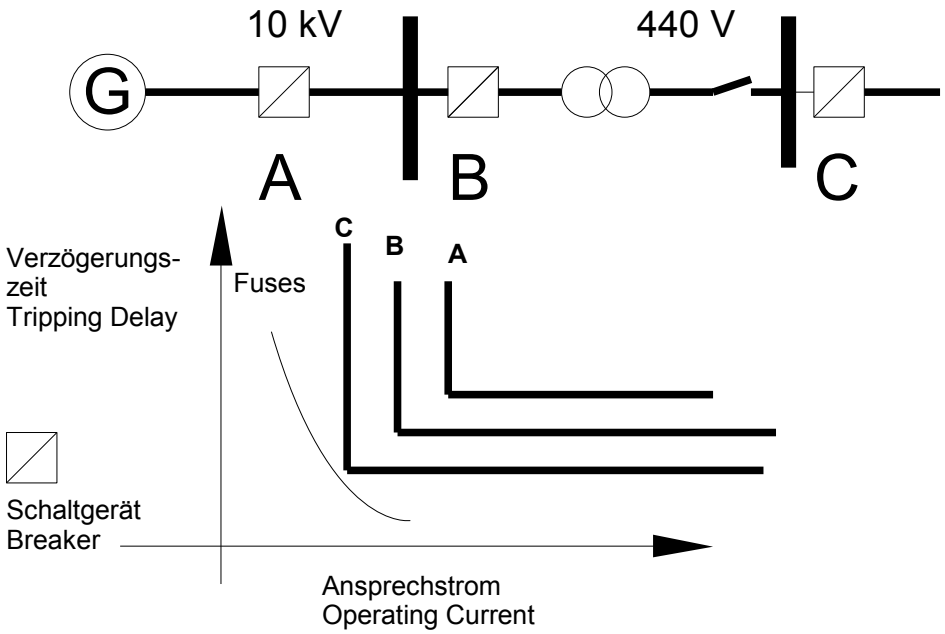
A short-circuit inside an electrical component causes a high current over the feeding breaker(s). A timer is activated as long as the current limit is exceeded: If the timer reaches the given time limit (delay), the predefined action (mostly trip of the breaker) is taken. The protection function is therefore called an (current-independent) overcurrent time protection. It is often called **instantaneous**, because delay time is well below a second.

Settings (2 Steps):

Current limit *(Par.1)***, time delay** *(Par.2)***, function code** *(Par.101)*

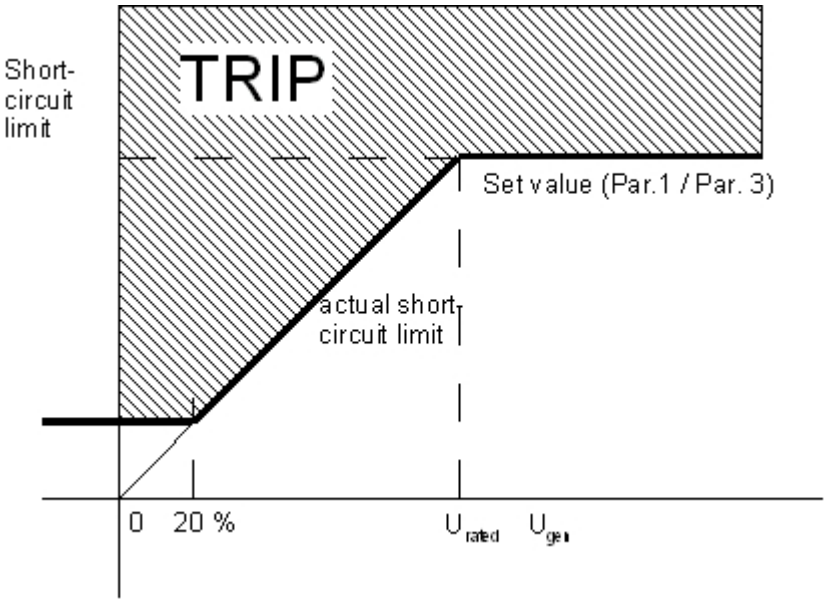
Current limit *(Par.3)****, time delay*** *(Par.4)****, function code*** *(Par.102)*

Overcurrent time protection must be adjusted in a way, that as few as possible components are switched off. This is achieved by use of different time delays (discrimination). Time delays are choosen in such way, that the circuit breaker located nearest to the fault will tripped first:



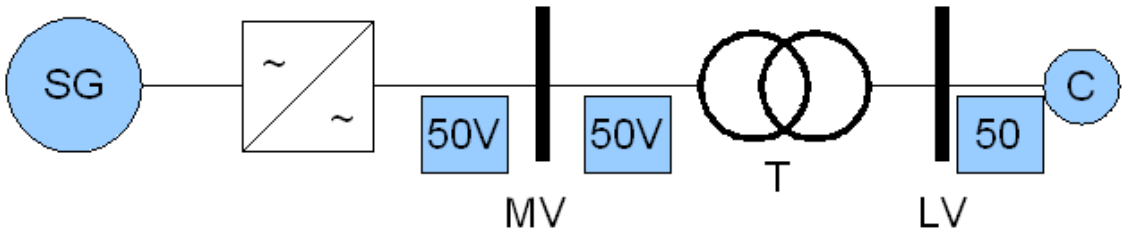
Drawing 4.1.1 Setting of time delay and current limit (Discrimination)

ANSI 50 is linked to network protection. The function protects the network against faulty devices (short-circuits). Settings of overcurrent protection (ANSI 51, 4.1.5.5, 4.1.5.6) and undervoltage protection (4.1.6.1) had to be taken into account. Both short-circuit functions may be used as Voltage Restrained Overcurrent VRO protection:



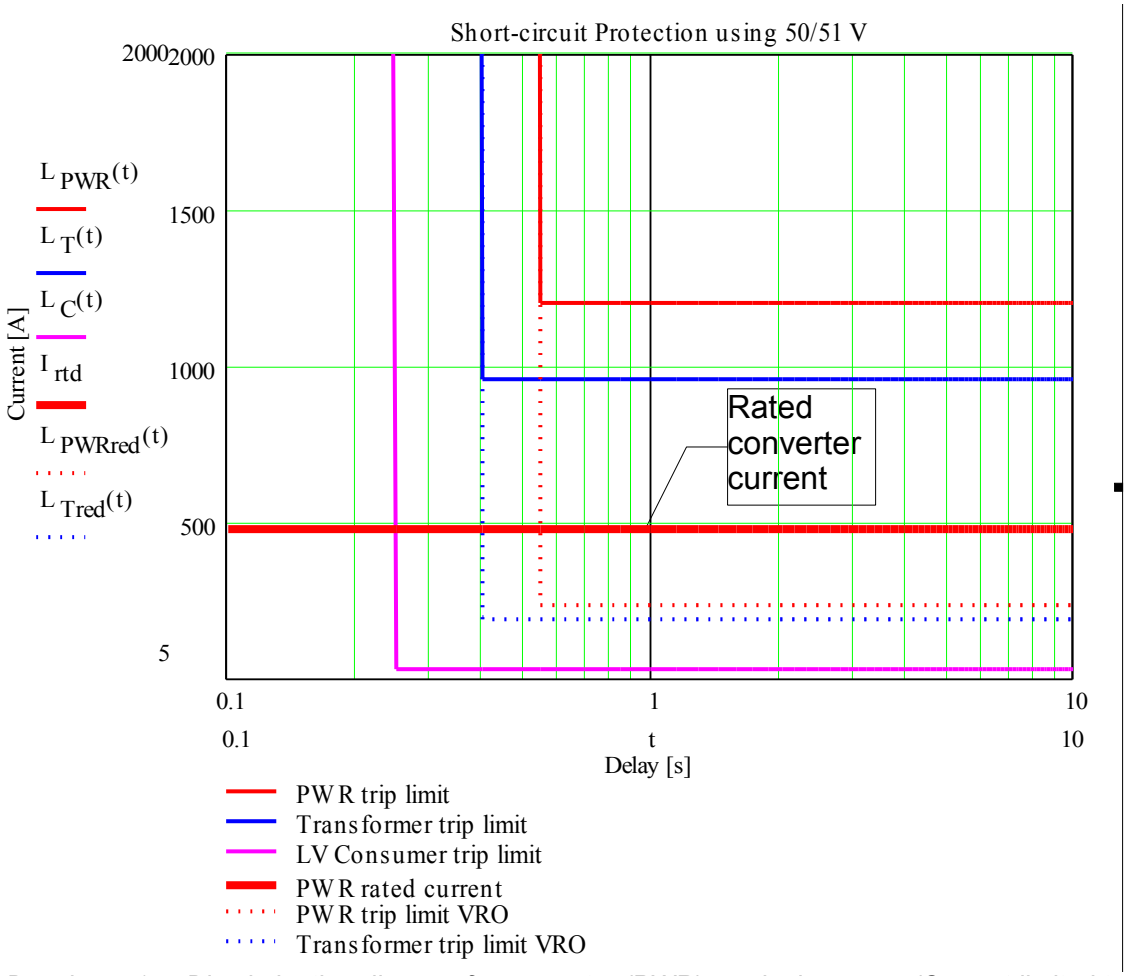
Drawing 4.1.2: Trip limit related to mains voltage

The short-circuit trip limits are dynamically reduced with the voltage to achieve proper discrimination even in case of “weak” generators (e.g. Shaft-generators using converters):



Drawing 4.1.3: Medium-voltage shaft-generator feeding network

The SG-converter combination may not deliver enough current to trip the transformers conventional short-circuit protection if the transformers rated apparent power is equal to the shaftgenerators. In that case the VRO-mechanism will help by reducing the trip settings with the voltage (dotted lines in the following drawing):



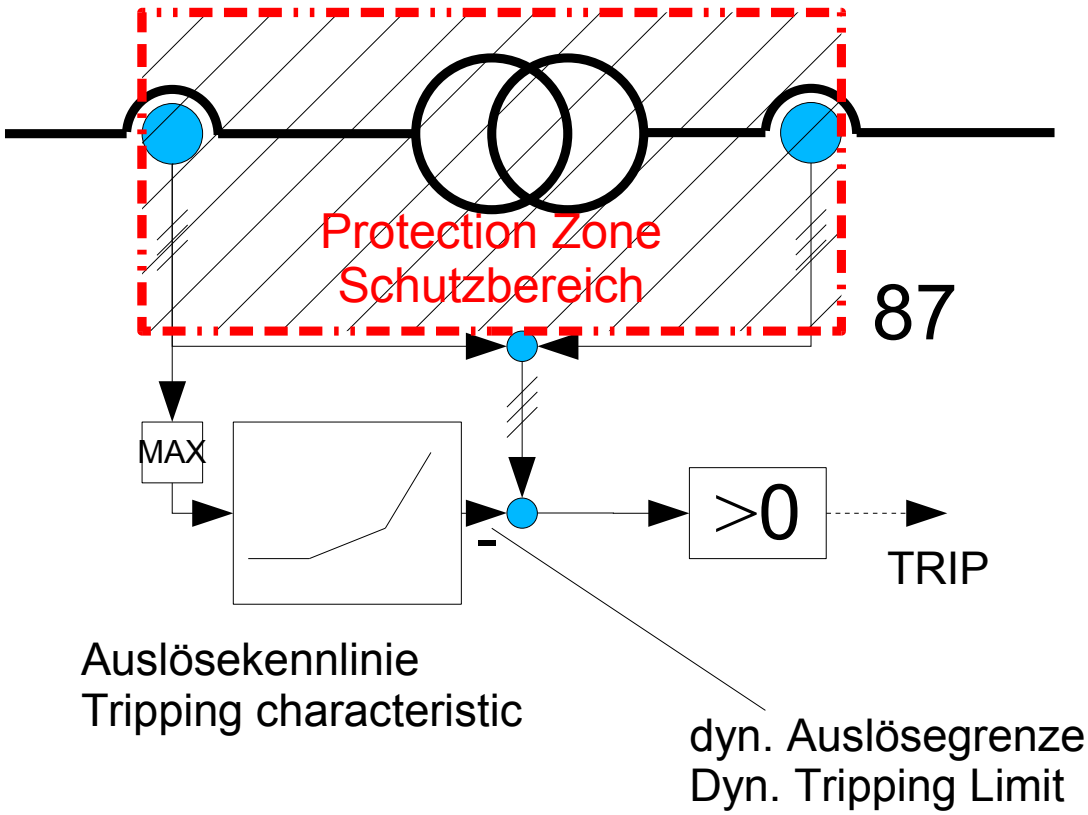
Drawing 4.1.4: Discrimination diagram for converter (PWR) as single source (Current limited to rated current)

4.1.5.2 Locked Rotor

One of the Short-circuit (ANSI 50) functions can be blocked for a certain time interval during start of a motor. After that the function is released. In case of a subsequently blocked rotor (increased current) the breaker will be tripped by the now active function.

4.1.5.3 Differential Protection (ANSI 87)

Differential protection compares currents on both sides of an electrical component. Only faults located between current transformers connected to the protection devices may be detected. So any faulty component may be disconnected in shortest possible time without taking into account the discrimination scheme. Consequently the differential protection mechanism has no adjustable delay time.

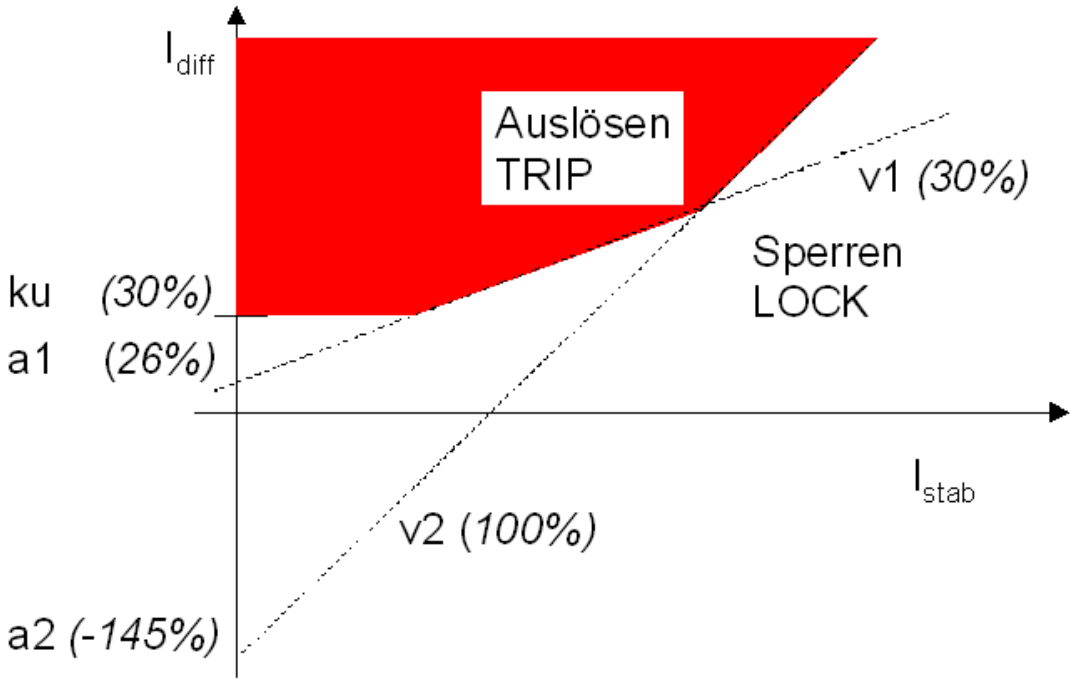


Drawing 4.1.5: Tripping curve (Input is maximum current of one system)

Nevertheless there are some parameters regarding tripping characteristic and inrush stabilization:

- **Tripping characteristic:** Differential protection shall not trip, if high currents are flowing just **through** the electrical component protected (e.g. short-circuit outside the area of protection). Accuracy of current transformers decays absolutely as well as relatively with increasing current. So the tolerable current difference should not be defined as a constant value but had to be calculated dynamically depending on the actual current.

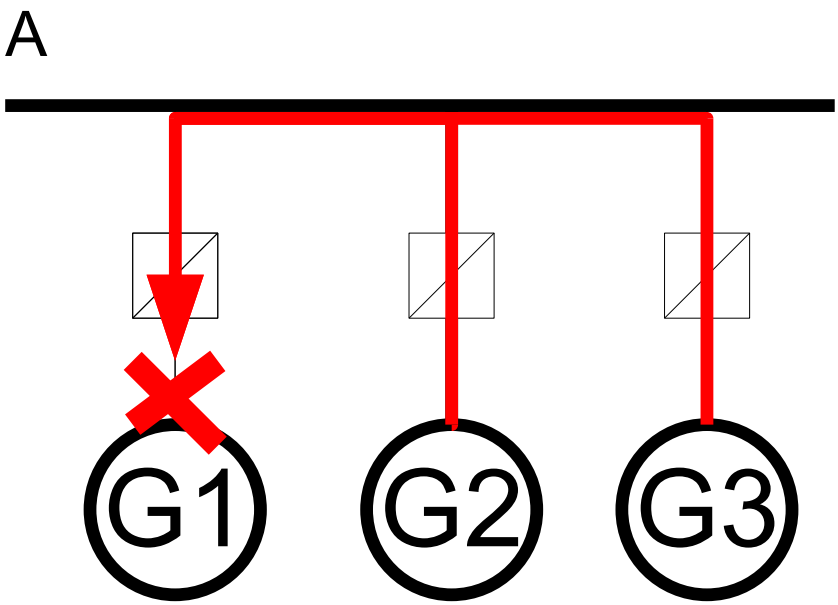
Tripping characteristic may be defined by parameters. Differential protection of transformer requires definition of transformer ratio and phase shift.



Drawing 4.1.6: Tripping characteristic ANSI 87 (Standard settings in italics) . I_{stab} is max current measured by the three SLE500s transformers.

- **Inrush stabilization:** Transformers may take very high currents after being connected to mains voltage (Inrush). There is no equivalent current on the secondary side of the transformer, so the criterion of the differential protection may met. An inrush stabilization avoids tripping by mistake: Characteristic for inrush currents are second -order harmonics. These are detected by the protection device and used to lock the differential protection if their value is higher than a set value. (For adjustment of inrush stabilization refer to 2.1.7.2.) Inrush stabilization is also active with generators to avoid tripping of generator breakers by differential or instantaneous overcurrent protection after connecting large transformers.

Differential protection is perfect for protection of components, it increases also reliability of the whole network as shown:



D 4.1.7: Missing discrimination in case of generator-internal faults

Short-circuit inside generator G1 leads to loss of supply for busbar A, because “instantaneous overcurrent”/”short-circuit” protection (ANSI 50) trips all generators (G1,G2,G3) circuit-breakers because the protection function is non-directional. Differential protection identifies the faulty generator with minimal delay and therefore before tripping any breaker by “instantaneous overcurrent”/”short-circuit” protection (ANSI 50)

Generator differential protection shortens blackout on busbar A. It should be taken into account, that breakers tripped by “instantaneous overcurrent”/”short-circuit” protection (ANSI 50) mostly require manual operation (RESET, ACKNOWLEDGE) to become operable again. So blackout time is increased, especially in unattended operation!

Settings:

***Tripping characteristic*:**

ku	**Minimal current difference (Standard 30%)**	*(95)*
a1,v1	**Offset and gradient (26% / 30%)**	*(96,97)*
a2,v2	**Offset and gradient (-145% / 100%)**	*(98,99)*

Inrush stabilization:

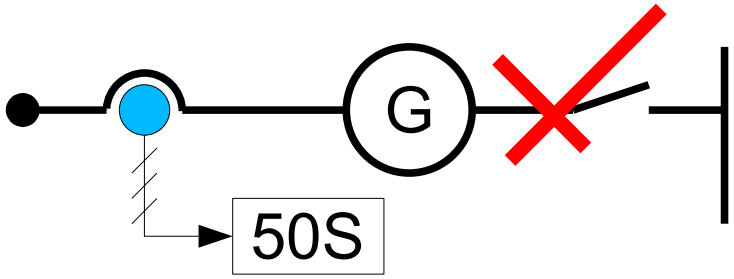
Limit of 2. Harmonic *(94)*

Function code *(132)*

[1]

4.1.5.4 Stator protection (ANSI 50)

Stator protection is an Instantaneous Overcurrent protection with reduced current trip limit. Stator protection is only active, when breaker is open and should be open[2]. Stator protection protects starting or idle generator in case of internal faults. Current transformers must be located at the starpoint of the generator.



D 4.1.8Stator protection with current transformers located near the starpoint.

It makes sense to stop and de-excite the generator in that case to avoid additional damage! Component protection!

Settings: Current limit *(Par.5)* **and delay time** *(6)*, **function code** *(103)*

4.1.5.5 Overcurrent protection (definite time) (UMZ, ANSI 51)

Overcurrent protection works similar to instantaneous overcurrent protection (4.1.5.1). Delay times are increased, while current thresholds are lower. Scope is protection of electrical components, so proper discrimination must not be discussed.[3] Trips by overcurrent protection may worsen the situation for other components.

Often mechanisms for load reduction are used before disconnecting a component(“Preferential trip”, pitch reduction with thrusters etc.) A prealarm may be used to allow manual load reduction by the operator on duty.

Settings:

Current threshold *(7)*, **delay** *(8)*, **function code** *(104) (“Alarm”)*

Current threshold *(9)*, ***delay*** *(10)*, ***function code*** *(105) (“Prealarm”)*

4.1.5.6 Overcurrent, inverse time (AMZ, ANSI 51)

It is often difficult to protect an electrical component by overcurrent protection of the definite-time type: Current may be just below the threshold and definite-time-type function

1 Transformer ratio and phase-shift are also settings related to differential protection.
2 Avoids tripping by missing feedback signal! (New feature 271.001020.F9)
3 The right question: Are the components designed and selected meaningfully?

will never trip. Or current may be well above the threshold, but only for time lower than set as definite delay. Correct settings may be difficult to find especially for directly started asynchronous motors. The overcurrent - inverse time - mechanism allows to make the trip delay dependent from the actual current.

Two assumptions are made:

- Losses of the machine are depending from the current square (I^2)
- The machine can only radiate losses at 102.5 % rated current, additional losses are stored in the machine and raise the temperature of the machine!

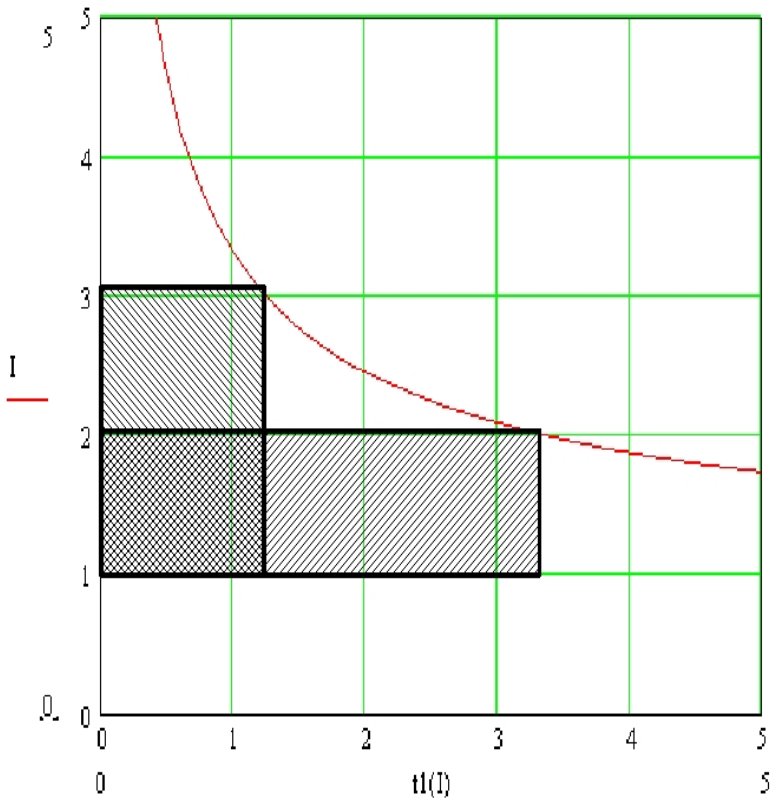
If a certain current is allowed for a certain time, other pairs of current and time may be calculated using the assumptions stated above. In fact, in infinite number of pairs may be calculated using the following form:

$$t_{TRIP} = \frac{K}{\frac{I^2}{I_n^2} - 1.05}$$

That is quite similar to the so-called “extremely-inverse” characteristic defined in IEC 60255-3 respective BS 142 (t_I = time constant):

$$t_{TRIP} = \frac{80\,t_I}{\frac{I^2}{I_n^2} - 1}$$

A current-dependent trip delay may be used to get a fuse-like tripping characteristic.



D 4.1.9: 300% 1.25 s and 200 % 3.3 s are making the same thermal load for the device (K=10 s)

The GPM500 uses the “extremely- inverse”-characteristic: Overcurrent protection of this type needs just one setting (K). Very high currents lead to extremely short trip delays, curve should be plotted in the discrimination diagram. Protection function is of restricted-memory type[1].

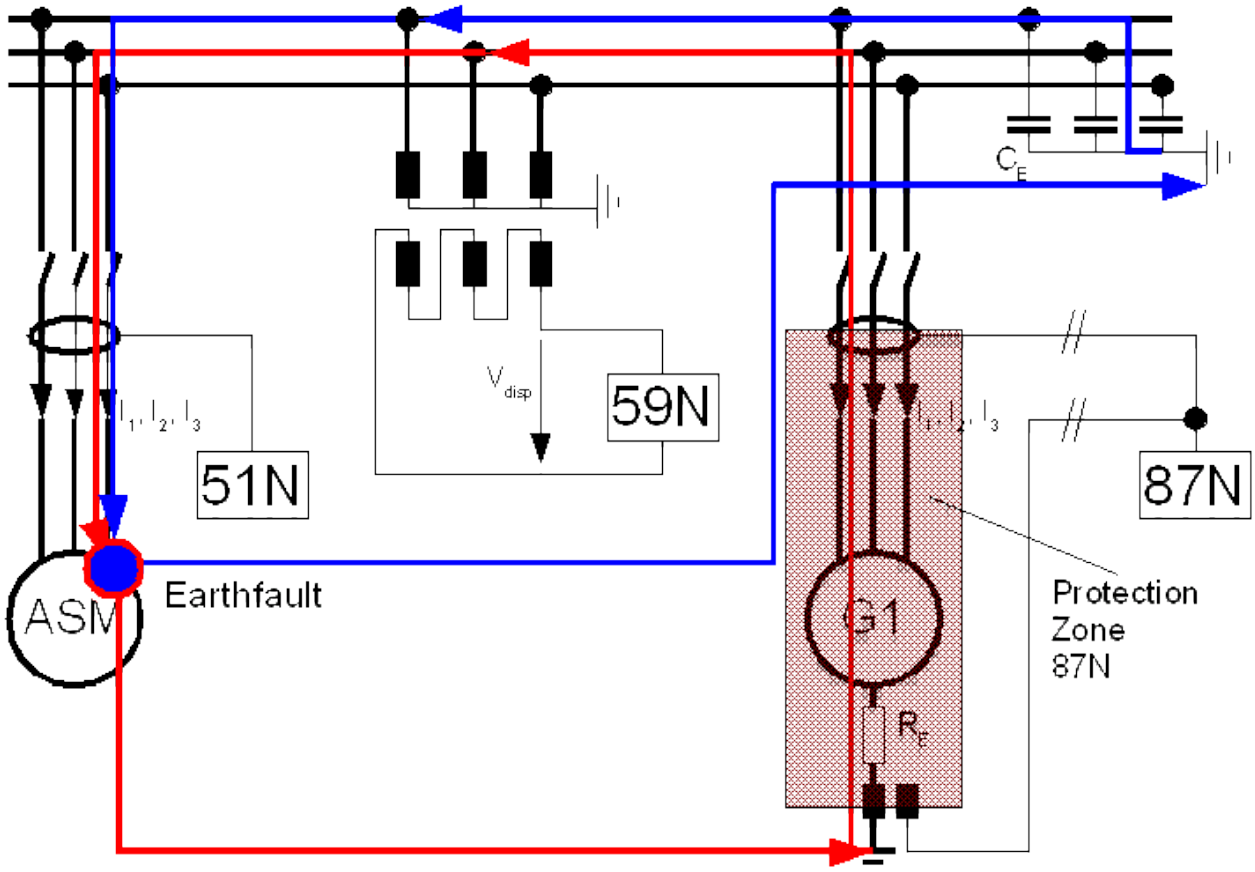
Settings: (2 steps)

K_1 *(81)*, **Function code** *(141)*

K_2 *(82)*, **Function code** *(142)*

4.1.5.7 Earthfault protection (51N, 87N)

Detection of earthfaults in isolated networks can be effected using different techniques:



Earthfaults have two measurable effects:

- System of voltages between conductor and ground is shifted, sum of these voltages (displacement voltage) in not more equal to zero.
- A ground current flows into the ships hull at the place of earthfault, this current loop is closed via the networks (cable-) capacitances.

The first effect can be used to proof the **existence** of an earthfault (Displacement ANSI 59N, refer to 4.1.6.3), the second effect may be used to find out the **location** of an earthfault (ANSI 51N, 87N).

1 Current^2 is integrated in the memory for current values above 102.5 % , memory value is reduced, if current is between 102.5 % and 0 %.

Fault current I_E can be found as a zero-sequence system in the cables:

$$I_1 + I_2 + I_3 = I_E \quad .$$

This sum can be measured by use of current transformers surrounding all three conductors.

In most plants earthfault current I_E is increased by connecting generators starpoints to ground (ships hull) via resistors R_E [1]. The pure capacitive current I_E is enlarged by a resistive component to reduce arcing at the place of fault. The enlargement of earthfault current makes its detection easier as well.

Earthfault protection of generators with such starpoint resistors is impeded by the fact, that the resistive part of the earthfault current is flowing through the generator anyway. It makes no significant difference, whether the earthfault is **inside** or **outside** the generator. A simple overcurrent protection for the zero-sequence-current (ANSI 51N) will not solve the problem for the generator. It may be possible to use a directional overcurrent protection (ANSI 57N) for this task, we prefer another mechanism to avoid the uncertainties of directional decisions:

The standard protection of type 51N for consumers is replaced by a differential protection for zero-sequence systems (87N, refer to diagram). In case of an earthfault **outside** of the area of protection only the resistive current component is flowing through the generator and is passing both current transformers, so that the difference is zero. While in case of an eartfault **inside** the generator the difference between the zero-sequence current through the starpoint and to the mains can not be zero, because the earthfault current leaves the area of protection without passing an current transformer.

Remark: If the starpoint resistor is not designed for permanent load another, independent protection mechanism must be used to protect the resistor (59N, 51N).

Earthfault Settings (51N, 87N):

Current threshold *(47)*, **delay** *(48)*, **Function code** *(124) ("Alarm")*

Current threshold *(49)*, ***delay*** *(50)*, **Function code** *(125) ("Prealarm")*

4.1.5.8 Unbalanced Current (asymmetry) (ANSI 46)

Rotating machines may be destroyed if phase currents are different. Unbalanced current in the stator causes a contra-rotating field in the air gap, which induces voltages in the rotors coils and causes additional losses.

Rotating machines rotors are protected by the ANSI46 mechanism: Difference between highest and lowest phase current is calculated and should not exceed the given limit.

Settings (46):
Current threshold *(11)*, **delay** *(12)*, **Function code** *(106) ("Alarm")*

Current threshold *(13)*, ***delay*** *(14)*, **Function code** *(107) ("Prealarm")*

4.1.6 Voltage-related Protection Functions

4.1.6.1 Undervoltage (27)

Undervoltage protection is as well network protection as component protection. It is an important mechanism for the protection of rotating engines: The maximal torque of a

1 A special transformer-resistor combination may be used for the same purpose!

synchronous machine is directly proportional to its voltage, while the max torque of asynchronous machines is proportional to the square of the voltage.

The undervoltage protections customary setting is 60% of the rated voltage, so maximum torque of asynchronous machines is at least reduced to 36% of its value at rated voltage. With most asynchronous motors this torque is more or less above their rated torque, what means, that the motor will not stop.

Undervoltage protection is therefore not needed with transformers, it is nevertheless often used, to enforce a definite start position after blackout[1].

Undervoltage protection is very important for generators running solo: An underexcited generator must be disconnected to allow connection of a standby generator[2].

Settings: (2 steps)

Voltage threshold *(15)***, delay** *(16)***, Function code** *(108)*

Voltage threshold *(17)***, delay** *(18)***, Function code** *(109)*

4.1.6.2 Overvoltage (59)

Overvoltage function protects all producers and consumers but should only be activated with components able to produce overvoltage: Generators, capacitor and filterbanks. Generators should be stopped and deexcited in case of overvoltage.

Settings: (2 steps)

Voltage threshold *(19)***, delay** *(20)***, Function code** *(110)*

Voltage threshold *(21)***, delay** *(22)***, Function code** *(111)*

4.1.6.3 Voltage Displacement / Ground overvoltage (59 N)

Displacement voltage is the sum of three conductor-ground-voltages in a isolated three-phase network. The displacement voltage is normally zero. The appearence of a displacement voltage indicates an earthfault without giving information about its location. A special transformer winding is used to obtain the displacement voltage (normally designed in such way, that at rated voltage on the primary side and full displacement a secondary voltage of 100 V can be obtained) :

$$\underline{V_{disp}} = \frac{\underline{V_{10}} + \underline{V_{20}} + \underline{V_{30}}}{3}$$

The earthfault can be located only by measuring the zero-sequence currents (refer to 4.1.5.7). Normally the 59 N protection is connected in parallel to a resistor, which dampens oszillations cause by ferro.magnetic effects.

Settings: (2 steps)

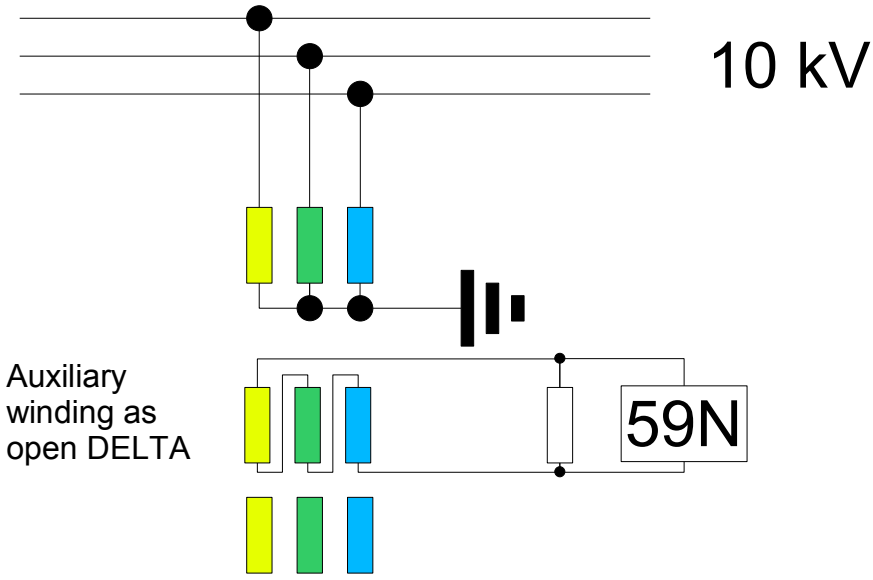
U_0-Voltage threshold *(51)***, delay** *(52)***, Function code** *(126)*

U_0-Voltage threshold *(53)***, delay** *(54)***, Function code** *(127)*

---

1 If transformer breakers remain closed in case of blackout, standby generator will suffer an extreme inrush after closing its breaker. So undervoltage protection should only be deactivated for transformers feeding important consumers (rudder machine, emergency devices etc.)

2 The standby generator may be started by an undervoltage prealarm to reduce the blackout time. So the standby generator can be connected immediately after disconnection of the faulty generator (refer to start passing!)



D 4.1.10Schematic of auxiliary winding for voltage displacement

4.1.6.4 Phasefailure & Phase-sequence

Phase sequence and difference between phase voltages (rms) is checked. An alarm may be activated by setting the appropriate function code. Maximum phase voltage and minimum phase voltage should be below 20% of the rated voltage and following in the right (positive) sequence to avoid an alarm.

Phase failure protection is important for generators: Defunct or wrongly connected voltage transducers may be detected before connecting the generator!

Settings:

Function code *(146)*

4.1.7 Frequency-related Protection Functions

4.1.7.1 Underfrequency (81L)

Underfrequency is mostly caused by insufficient power generation, onboard ship often caused by problems with fuel supply (filter!). Protection function is used almost exclusively for generators. Its should be taken into account, that underfrequency trip can be only be the last option, because it worsens the situation. It makes sense to use an underfrequency protection for preferential tripping of not so important consumers.

Settings: (2 steps)

Frequency threshold *(23)*, **delay** *(24)*, **Function code** *(112)*

Frequency threshold *(25)*, **delay** *(26)*, **Function code** *(113)*

4.1.7.2 Overfrequency (81H)

Overfrequency may be caused by disturbed speed controllers and dynamically also after disconnection of major loads. Overfrequency is caused by the generator, protection function 81H will only be activated in generators to protect the network.

Settings: (2 steps)

Frequency threshold *(27)*, **delay** *(28)*, **Function code** *(114)*

Frequency threshold *(29)*, **delay** *(30)*, **Function code** *(115)*

4.1.8 Protection functions related to Power & Reactive Power

4.1.8.1 Reverse power (32)

Prime movers like diesel engines may be damaged if driven by their generator for a longer time. It is impossible to prevent synchron generators from working as motors, so reverse operation must be detected by the protection device.

Ships with electrical propulsion system need a often a limited capability to take reverse power by the generators while reversing the electrical propulsion motors. It must be taken in account, that disconnection of an generator by reverse power protection (or overfrequency protection as well) worsens the situation.

Settings: (2 steps)

Reverse power limit *(31)*, **delay** *(32)*, **Function code** *(116)*

Reverse power limit *(33)*, **delay** *(34)*, **Function code** *(117)*

4.1.8.2 Underload (37)

Underload means that a component takes less power than exspected. Underload protection is used with **motors** to detect mechanical faults (broken shaft, idle pump). Protection 37 is used with **generators** to indicate an unhealthy operating condition, **not for trip**! Alarm is suppressed in solo operation **of generators!**

Settings:

Minimal power *(59)*, **delay** *(60)*, **Function code** *(130)*

Minimal power *(61)*, **delay** *(62)*, **Function code** *(131)*

4.1.8.3 Under-excitation (40)

Faults in the excitation system may force a synchronous generator to behave as an asynchronous generator. The generator continues to send power in the network, the reverse power protection will not work. Under-excitation protection may be implemented as a comparative method: Reactive power of generators running in parallel should share their reactive load evenly. This method requires exchange of reactive power values via data link, so we prefer to use a criterion which uses only process data of the own generator:
The maximal reactive power consumption possible for a synchronous generator without falling out of synchronism can be taken from vectorial diagrams of the generator. Precisely

calculated, it is depending from the generators load, but for ship´s generators an rough estimation will be sufficient. Because of the almost inductive load on board common vessels reactive power consumption of generators must not be driven to the physical limits. So a definite limit may be used to detect loss of field/under-excitation:

e.g. $S_{reaclim} \sim 0.6\sqrt{3} * U_{rtd} * I_{rtd}$

Settings: (2 steps)

Reactive power limit *(55)***, delay** *(56)***, Function code** *(128)*

(may be used for protection against positive reactive power in the future, blocked rotor of ASM)

Reactive power limit *(57)***, delay** *(58)***, Function code** *(129)*

4.1.9 Preferential Trip (Current- and Frequency-related)

Up to five groups of consumers may become disconnected in case of overload and/or underfrequency. Any step of preferential tripping may initiated by both criteria, so three parameters have to be assigned to every step:

Settings (5 steps):

Step 1: Current/power limit *(37)* **, frequency limit / mode sel.***(38)***, delay time** *(119)*

Step 2: Current/power limit *(39)* **, frequency limit / mode sel.***(40)***, delay time** *(120)*

Step 3: Current/power limit *(41)* **, frequency limit / mode sel.**(42)**, delay time** (121)

Step 4: Current/power limit (43) **, frequency limit / mode sel.***(44)***, delay time** *(122)*

Step 5: Current/power limit *(45)* **, frequency limit / mode sel.***(46)***, delay time** *(123)*

Bit 15 of the respective frequency limit can be set to select power limitation instead of current limitation.

GPM500 supports different ways of preferential tripping (depending on class and owner):

- In case of generator trip consumers will be disconnected immediately by the affected generators GPM without considering generator current and frequency and whether the remaining generators are capable of taking the load.
- In case of generator trip consumer will be disconnected immediately (almost) by the Unaffected generators GPM taking into account their generators current and frequency. A special telegram is used by the tripping GPM to force the delay to zero for the other GPM of the affected subnet (refer to 5.1.5, p. 51)

Current/power and frequency thresholds should be set to 400% rated current/power and 0 Hz to disable the respective step.

An additional DIO500 must be provided to implement steps 4 and 5. DIO500 must be activated by setting Par. 104, Bit 15 to “1”!

4.1.10 Startfailure

Start command by GPM500 starts a monitoring mechanism, which gives an alarm with a

certain delay. The monitoring mechanism is deactivated, if circuit breaker is closed or generator is ready to synchronize.

Common reaction may be start passing, to get another generator started and connected.

Settings:

Monitoring time *(Par.83)*

Function code *(Par.143, lower Byte)*

4.1.11 Stopfailure

Stop command either by PMS (Power Management System) or by the operator activates stop monitoring. The generator set should be brought to standstill within the monitoring time. Standstill is assumed, if generator voltage < 10% U_{rated}.

Reaction must be choosen by the operator, it is recommended to let the engine run idle until operator decided to reconnect the generator or to stop manually.

Stopfailure alarm is inhibited while engine is cooling down!

Settings:

Monitoring time *(Par.84)*

Function code *(Par.144, lower Byte)*

4.1.12 Synchronization Failure

Breaker must be closed in a certain time interval after switch-on release. An alarm signal is given if breaker fails to close in that time.

Switch-on release requires:

- V_{gen12} , V_{gen23} , V_{gen31} > $V_{release}$ *(Par.185)*
- f_{gen} > V_{rated}/V_{rated} * f_{rated}
- Start signal[1] set (if Synchronization mode = 1 **"MAN"**)
- Synchronization mode = 1 **"MAN"** or Synchronization mode = 2 **"AUT"**
- Digital input DIO500#2:**DI7** set. (Busbar earthing open)
- **NO** trip command from any protection function

In case of blackout DIO500#2:**DI8** must be set in addition.

It will make sense to request another generator set in case of synchronization failure (Start Passing Relay option activated using the appropriate function code!). Generation of a stop command may not be a good reaction in case of sync failure because manual synchronization, manual tensioning of closing coil etc. are excluded in that case. Synchronization can finished by use of trip option in the function code. Synchronization will then be continued after acknowledging (resetting) the alarm.

Settings:

1 Start button on page 1 of BAT500 is flashing!

Monitoring time *(Par.87)*

Synchronizing mode *(Par.147, upper Byte)*

Function code *(Par.147, lower Byte)*

4.1.13 Starting Attempts (ANSI 66)

It is required by classification societies, to make several starting attempts in a certain time interval, at least for emergency generators. The protection device executes the predefined number of starting attempts in the time limit defined for start-failure (refer to 4.1.10).

This mechanism may not be used if another generator set may be started instead (start passing), so use of this mechanism may be restricted to emergency generator sets[1].

It should be made sure that no enginefailure signal (DIO500#1:16) is given during the first starts, if this causes start passing (SPR-bit set!)!

Settings: Number of starting attempts *(Par.143, lower Byte)*

Number of connections per time interval must often be limited to avoid thermal overload of asynchronous motors or filter banks. Number of possible starts is displayed below the "Start" touchbutton on page of the BAT500: "< x"!

Number of possible starts will be decreased by one after closing the circuit breaker and would be increased by one after the time interval (number of minutes). Use of this mechanism will be restricted to medium voltage motors and filter banks!

Settings:
Number of connections per .. *(Par.141, upper Byte)*
Time interval *(Par.142,upper Byte: Minutes)*

4.1.14 Breaker Failure

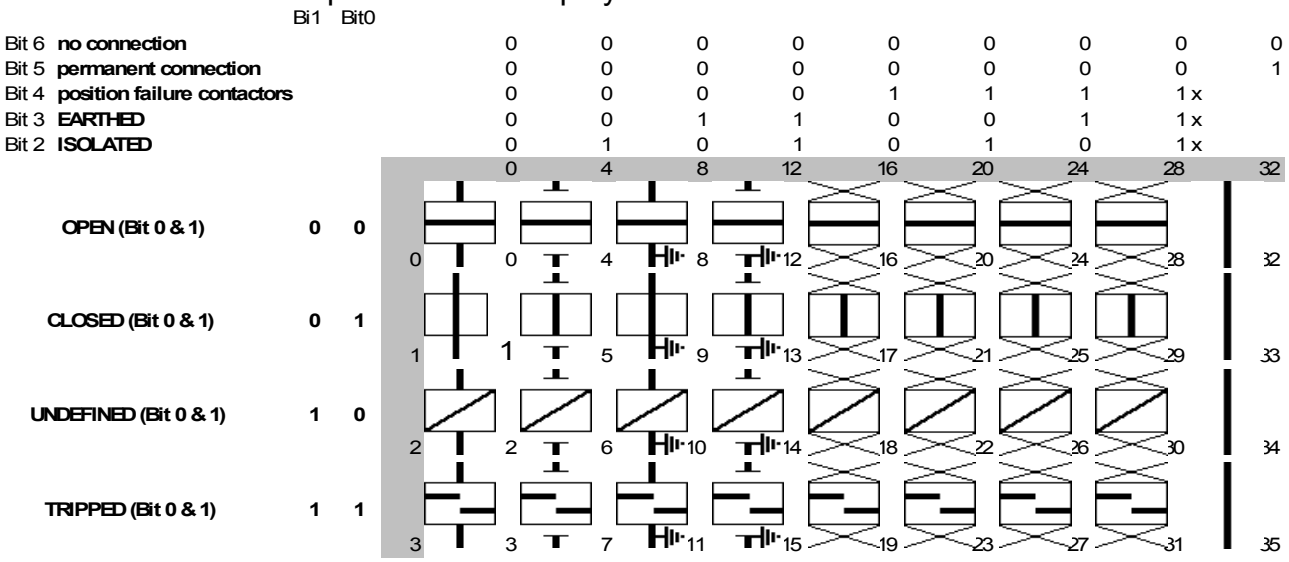
GPM500 evaluates different feedback signals regarding breaker position, position of the earthing contactor etc. Following pairs of signals may be monitored:

Signal 1	***Input contact***	***Signal 2***	***Input contact***	***Signal 2 evaluated, if Bit x set ...***
Breaker closed	DIO500#1:10	Breaker open	DIO500#2:14	Par.148, Bit 10 **("INV")**
Breaker in isolated position (drawn out)	DIO500#2:11	Breaker in operational position (inserted)	DIO500#2:10	Par.148, Bit. 8 **("TRE")**
Earthing contactor closed	DIO500#2:12	Earthing contactor open	DIO500#2:13	Par.148, Bit. 9 **("ERD")**

1 Please take into account, that starting attemps will be executed, until switch-on release is given (means generator voltage about 80%). If starter may not operated with an running diesel, start signal must interlocked with speed contact etc.

Signal 1	*Input contact*	*Signal 2*	*Input contact*	*Signal 2 evaluated, if Bit x set ...*
Control tripcoil	SLE500:7,8	Input tripcoil monitoring	SLE500:13,14	Par.148, Bit. 11 **(“COIL”)**
Set position Breaker CB	**EKGEISOLL (internal signal)**	Breaker closed	DIO500#1:10	ever
Set position closing spring	**TRUE**, wound up	Breaker ready	DIO500#2:9	ever

Breaker and contactor positions are displayed as follows:



GPM 500 provides no special signal for winding up the breakers closing coil. It is assumed, that breakers are winding up automatically after closing. Nevertheless GPM500 monitors whether the closing coil is tensioned[1]:

Status	Indication	Remark
Spring charged, Breaker ready		DIO500#2:9 on +24V internal
Spring relaxed, breaker not ready	 **FLASHING**	DIO500#2:9 open

Settings:
Function code *(Par.148) + bits 8,9,10 &11 (enabling additional functions, see above!)*

1 Neither blackout-connection nor synchronization will be performed in case of uncharged spring! Please connect DIO500#2:9 to +24V permanently, if no spring feedback is available!

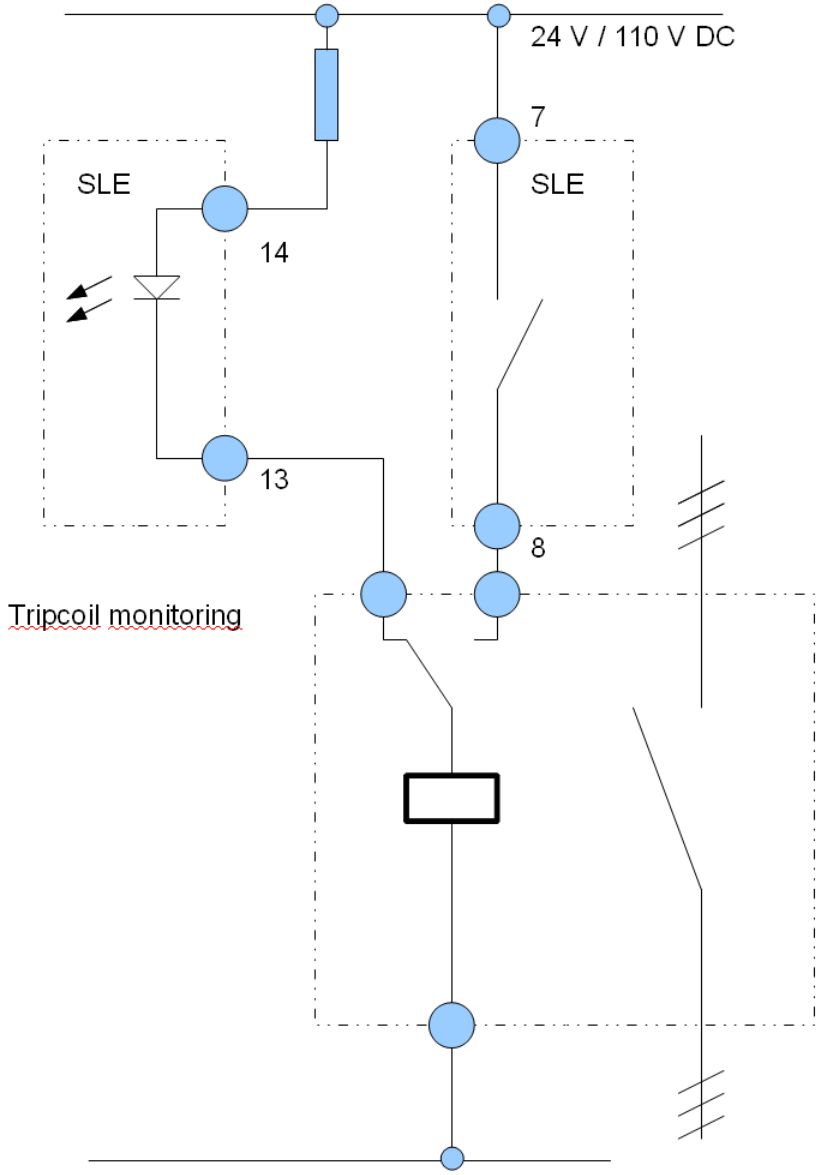


Diagram 4.1.1: Monitoring of tripcoil in case of shunt-trip operation

UNIT 5 Fieldbuses

5.1 CAN & CANopen

5.1.1 CAN1 & CAN2

The GPM500 may use a system of redundant CAN-buses (CAN1 & CAN2) to share process data for load balance, frequency regulation, spare power calculation etc. A proprietary protocol is is used, which is designed for transmission of large data blocks. The CAN-typical multicast allows all GPM access to the same data at the same time. Generator data is available in all GPM500 (stored in a data area), so spare as well as actual load distribution can be calculated by all GPM500.

5.1.2 Multiple-Master Operation

GPM500 uses CAN (Control Area Network) for communication with the touchpanel BAT500 according to the CANopen framework. CAN is also used for communication between GPM500, here a proprietary framework is used.

CAN is a field-bus which allows all participants to send unsolicited. The most important message will be transmitted undisturbed in case of collision, less important messages will be lost and must be repeated. Importance is defined by an identifier of 11 bit length. Lower identifier means higher priority.

5.1.3 CAN Protocol

CAN is an protocol invented for communication in cars, buses and other mobile applications. Payload is maximum 8 Byte per message, CAN uses no addressing mechanism (“This message is for device x!”) but uses an identifier as description of content (“This message is about theme y!”). Participants have to decide, whether the message is useful or not.

CAN provides not a master-slave communication as most field-buses, but is designed for communication in a group of peers. So a dedicated master is not needed.

5.1.4 CANopen, Index & Sub-index

CAN components became cheap because of the needs of automobile industry. For reasons of price and simplicity CAN was also adopted in the automation business. Additional frameworks were build up for industrial use, one of these is CANopen. CANopen introduces an Object Dictionary as data model. The memory of any device is accessible using index and sub-index. A special transmission mechanism called Service Data Object is used to read and write data of this dictionary. Additional network management functions (NMT-Master) and watchdog mechanism (Nodeguard) are defined by the framework.

5.1.5 Parallel Bus

Communication between GPM500 is provided by two parallel, redundant CAN buses (Internal name CAN 1 and CAN 2). The following telegram groups are used:

- **XPMBus:** All devices are sending and receiving telegrams with Identifier $500+Device No. These messages contain topological information like bus and network association and the requested spare power. Furthermore operation modes of load monitor are transmitted.
- **GMMBus:** Generators GPM send telegrams with Identifier $400+Device No.. Only

numbers between 1 and 12 should be used. Information like Power, rated power and frequency are transmitted to enable power sharing and power management. The messages are received by all devices and their reception is indicated by an 'X' on the HW-page.

- **FRECOBus:** Tiebreakers and shaft generators GPM have to take control over speed of generator sets when synchronizing or unloading. Telegrams with Identifier $300+Subnet-No. are used to change the frequency setpoints of the generator sets. Reception of the telegram is indicated by 'SLAVE' on the panel's HOME-page by the controled devices, the sending device displays 'MASTER'!
- **TRIP-message:** Spontaneous messages with identifier $200+Subnet-number are sent to inform other generator-GPM about tripping of one generator-breaker. This allows skipping preferential-trips delay time for the healthy generators (classification requirement GL!) and therefore nearly immediate unloading in case of overcurrent and underfrequency.
- **Preferential TRIP:** With introduction of the new motor-starter cubicles hardware-connections for tripping consumers will be replaced by dedicated CAN-messages!
- Additional telegram groups will be introduced to allow data transfer between IAMCS and GPM500 via Gateway and CAN1/2. *($540+Device No. for commands, $740+Device No. for command echo, $440+Device No. for measured data)*

CAN and the proprietary SAM framework for CAN 1&2 require use of unique device numbers for all GPM500 linked to one redundant bus. Generator numbers should be limited to the range 1 to 12, generally device numbers should be limited to 1 to 63!

5.2 Modbus

The main medium for communication between GPM500 and IAMCS is Modbus/RTU. GPM500 are designed to act as Modbus-slaves. A reduced subset of registers may be accessed for reading and writing using Modbus functions. The GPM500 uses its device-number also as its MODBUS-address, it supports MODBUS function codes 3 (Read Holding Registers), 6 (Preset Single Register[1]) and 16 (Preset Multiple Registers). All Registers are readable and writable, the access is restricted to mirror registers. So GPM-internal processes can not be tampered by the MODBUS-master.

	Slave Adr.	***Func -tion Code***	***Start Adr Hi***	***Start Adr Lo***	***No. of Reg. Hi***	***No. of Reg. Hi***	***Byte Count***	***Pay load***	***CR C***
Request	11	03	00	6B	00	02	--	--	
Response	11	03	--	--	--	--	4	ABC0DB00	
Request	11	06	00	6B	--	--	--	ABC0	
Response	11	06	00	6B	--	--	--	ABC0	
Request	11	10	00	6B	00	02	4	ABC0DB00	
Response	11	10	00	6B	00	02	--	--	

1 Mostly not used, allows EEPROM access for remote parametrization, not implemented yet!

It should be kept in mind, that the RS485-Interface for Modbus is a single interface without any redundancy. Different structures may be implemented according to requirements of owner and classification:

- GPM500 are connected in parallel forming one or more Modbus lines. Loss of communication between IAMCS and GPM500s will not affect the systems function because Power Management, Blackout-start etc. are functions of the GPM500. So only remote control and monitoring are lost in that case. **(IAMCS (a) in Diagram!)**
- Any GPM500 is connected individually. Communication loss is restricted to one device. **(IAMCS (b))**
- A fully redundant solution may me formed using interface modules (e.g. ZM432) gathering data from CAN1&2 and presenting them via modbus slave(s). Any bus link is doubled in this case but it should taken into account, that simple automation systems are not able to take data using redundant bus interfaces as the GPM500 does.**(IAMCS (c) [1])**

It may be desirable to place a second BAT500 for every generator inside the Engine Control Room (EMC/MCR) instead of using redundant interfaces.

1 Will be included in the standard 2010!

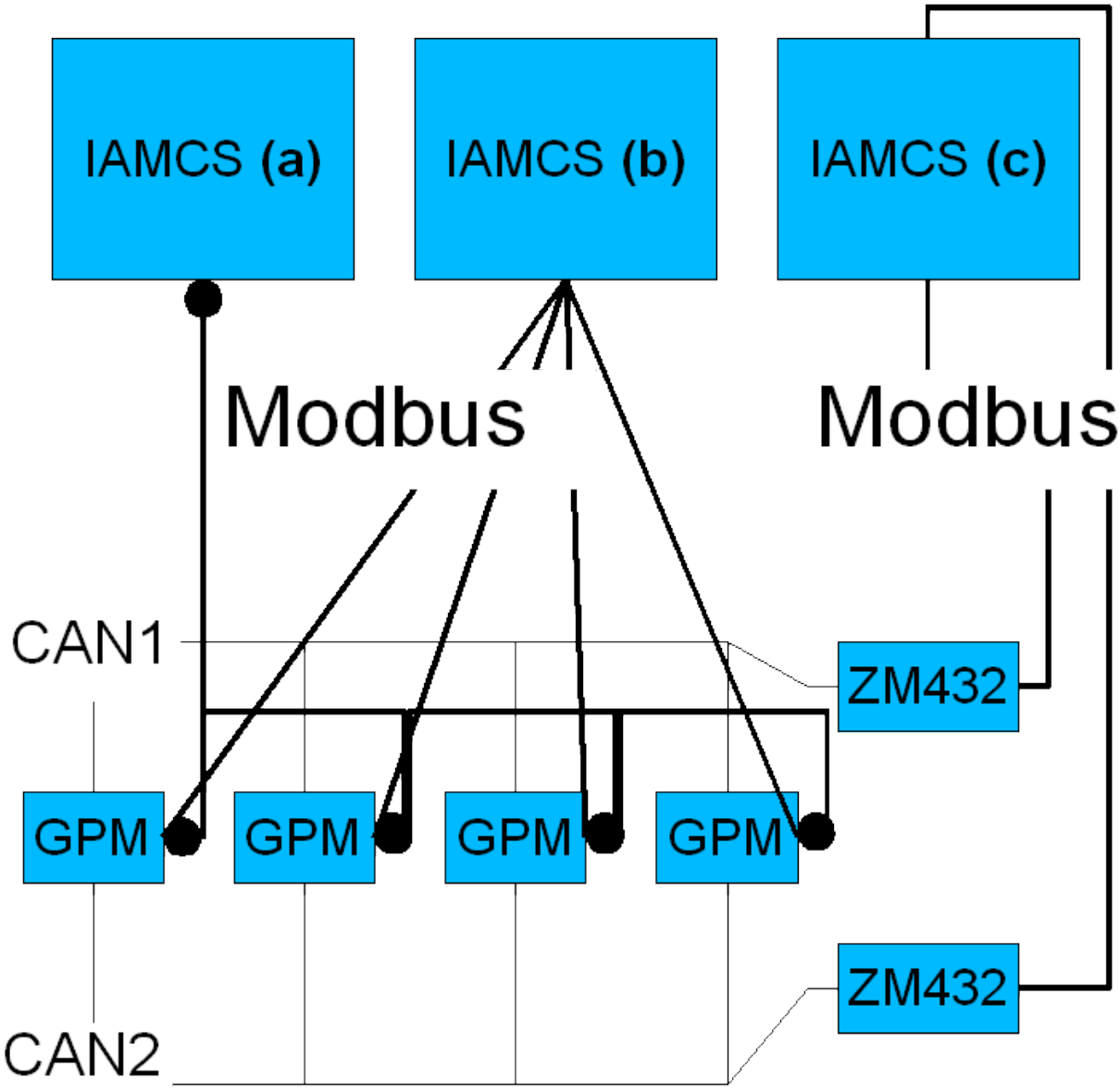


Diagram 5.2.1Modbus Interfaces

DAY 3

UNIT 6 Training 1: Codes, Tripping etc.

6.1 Synchronization

6.2 Parameters and Test functions

Most parameter pages allow setting of parameters as well as monitoring the respective function

6.3 Function codes, TRIP, STOP, DEEXCITATION

The GPM´s reaction in case of alarm may be defined :

Code / Bit Pos.			*Description*	*Value (hex)*	*Value (dez)*
OP	**OP**	**0**	In **OP**eration: Alarm is active. Otherwise all other bits are meaningless.	01	1
TR	**TR**	**1**	**TR**ip: Should trip with alarm.	02	2
DEX	**DEX**	**2**	**DE**e**X**citation: Generator to be deexcited, special function for consumers	04	4
STP	**STP**	**3**	**ST**o**P**: Generator to be stopped	08	8
ER	**LQ**	**4**	**L**ocal **Q**uit: **Heavy** fault, acknowledge (quit) after local inspection and only by pushbutton.	10	16
SWG	**SPR**	**5**	**S**tart**W**eiter**G**abe, **S**tart **P**assing **R**elay: Start command to be given for other generator, generator to be disconnected after other generator is ready to synchronize. [1] [2]	20	32
BL		**6**	**BL**ock, reaction maintained until alarm is acknowledged[3]	40	64
BBB		**7**	**B**us**B**ar**B**lock: No generator to be connected to the respective subnet *With combined Emergency/Harbour-Generator:* *Marks alarms, which should trip also in Emergency-mode (e.g. Short-circuit [50])*	80	128

It should be taken into account that STP is stopping a generator set without further delay while SPR is just opening the breaker and carries out a delayed stop (*Engine cooldown time Par. 176*).

UNIT 7 Interlocks & Synchronization

7.1 Switch-on Release

A premiss for synchronization as well as for connection to a voltage-free busbar (Blackout) is that the generator is running with at least minimum generator voltage and frequency (switch-on release) ![4] Positive sequence of the voltages is checked in addition.

7.2 Blackout-Interlock

To make a blackout-connection the GPM needs three independent signals:

1 Even if that will cause a blackout. In case of undervoltage or underfrequency a synchronization of the standby generator may be impossible, so the faulty generator must be disconnected before connecting the standby generator!

2 Start-passing may also be used with tie-breakers: If a tiebreaker should be opened e.g. by an over-current alarm, the tiebreaker's GPM starts with network-separation after 20 s. If necessary, additional generators will be connected by the GPM´s PMS and subsequently the tiebreaker will be unloaded and finally opened. If unloading is impossible, tiebreaker will be opened after delay given by Par. 90!

3 Example: Undervoltage alarm for a consumer should not lock the consumer until alarm is acknowledged (BL=0). While in case of a short circuit BL should be 1.

4 With tiebreakers minimum voltage and frequency must be obtained at least at one side!

- Blackout-input (DIO500#2:16) activated
- UP- or DOWN-voltage < 10 % U_{rtd}[1]
- No closed generator-breaker identified via CAN1/2

It should be taken into account that consumers have always blackout as long as the circuit-breaker is open! So the blackout-input should be activated permanently!

Please note that the three above mentioned signals are checked against each other, an alarm (“Voltage channel failure”, Par. 139) may be given in case of contradictions!

7.3 Synchro-Interlock

Only one breaker should be closed at the same time, so synchronizing as well as Blackout-connection is only allowed as no device with lower device-number is doing the same!

7.4 Shaft-Generator-Interlock

There are several interlocks regarding use of shaft-generators:

- Shaft-generators can not be connected as long another shaft-generator is connected (to the same subnet!).[2]
- Normally diesel-generators will be disconnected as long they are paralleled to an operating (and **not itself disconnecting**) shaft-generator. So diesel-generators can be connected (by hand or power-management) if the shaft-generators GPM got the STOP-signal first! Permanent paralleling is possible by setting Par. 189, Bit 5!
- A “Stopfailure”-alarm can be activated in any GPM if it detects shaft-generators and diesel-generators feeding the same subnet. This allows trip of a tiebreakers or transformer breakers to separate shaft-generators and diesel-generators!

7.5 Harbor-Generator-Interlock

Sometimes emergency-generators should also be used as harbor-generators. Main diesel-generators will be disconnected when the harbor-generator is operating (Harbour Operation). Harbor operation can be finished by starting a main generator, in that case the harbor generator will be unloaded, disconnected and finally stopped after cooling down.

7.6 Synchronizing (25)

7.6.1 Syncro-Check

Synchronism between generator voltage and mains voltage had to checked before closing the generator breaker. The conventional criteria are used:

- Voltage difference (Difference between RMS values of mains voltage U_{12} and generator voltage U_{12})
- Frequency difference
- Phase-angle (Distance of zero-transitions of voltages)

1 With generators the DOWN-(mains-) voltage must be < 10%, UP- (generator) voltage < 10% is not accepted!

2Nevertheless it is possible to connect two shaft-generators at the same time using a hardware-connection!

As an additional criterion the RMS-value of the levitation voltage U_{lev} (Generator voltage-Mains voltage) is introduced and included in the closing path. U_{lev} < set value is fully redundant to the other criteria, it takes into account deviations of the voltages curves.

ANSI 25: Synchronisation – Phase Angle [°] *(181)*
ANSI 25: Synchronisation – Voltage Difference [%] *(182)*
ANSI 25: Synchronisation – Frequency Difference [0.01%] *(183)*
ANSI 25: Synchronisation – Voltage Levitation [%] *(184)*

7.6.2 Synchronization and Closing

The ZKG500 as well as the SLE500 are checking independently, whether mains and generator voltage are synchronized. Both modules must generate the CLOSING command at the same time, both digital signals are needed to activate the closing relay of the SLE500 (hardwired AND). CLOSING command of ZKG500 will be transmitted to the SLE500 via external wiring (ZKG500:16 -> SLE500:32).

7.6.3 Synchro-Controller

The GPM is not only checking synchronism but is also making generators synchron to mains. The synchro-controller uses the relay outputs of the GOV500 to control the diesels governor.

Two synchronization modes may be chosen:
- Synchronization starts automatically when switch-on release is given (Par.147, Bit 9 set, AUT on Synchronizing page)
- Synchronization starts only, if GPM500 gets an START command (Par.147, Bit 8 set, MAN on Synchronizing page)

Automatic synchronization as well as automatic BLACKOUT-connection should normally be disabled with consumers[1]!
If GPM500 are connected by CANbus, only one protection device per subnet is allowed to synchronize. Synchronization for the device with the higher device number is interrupted, synchronization will be continued in order of their device numbers.

Load distribution: Amplification Synchronizing control [%] *(192)*

1 Some consumers may be reconnected automatically after blackout, here an automatic connection mechanism may have its place!

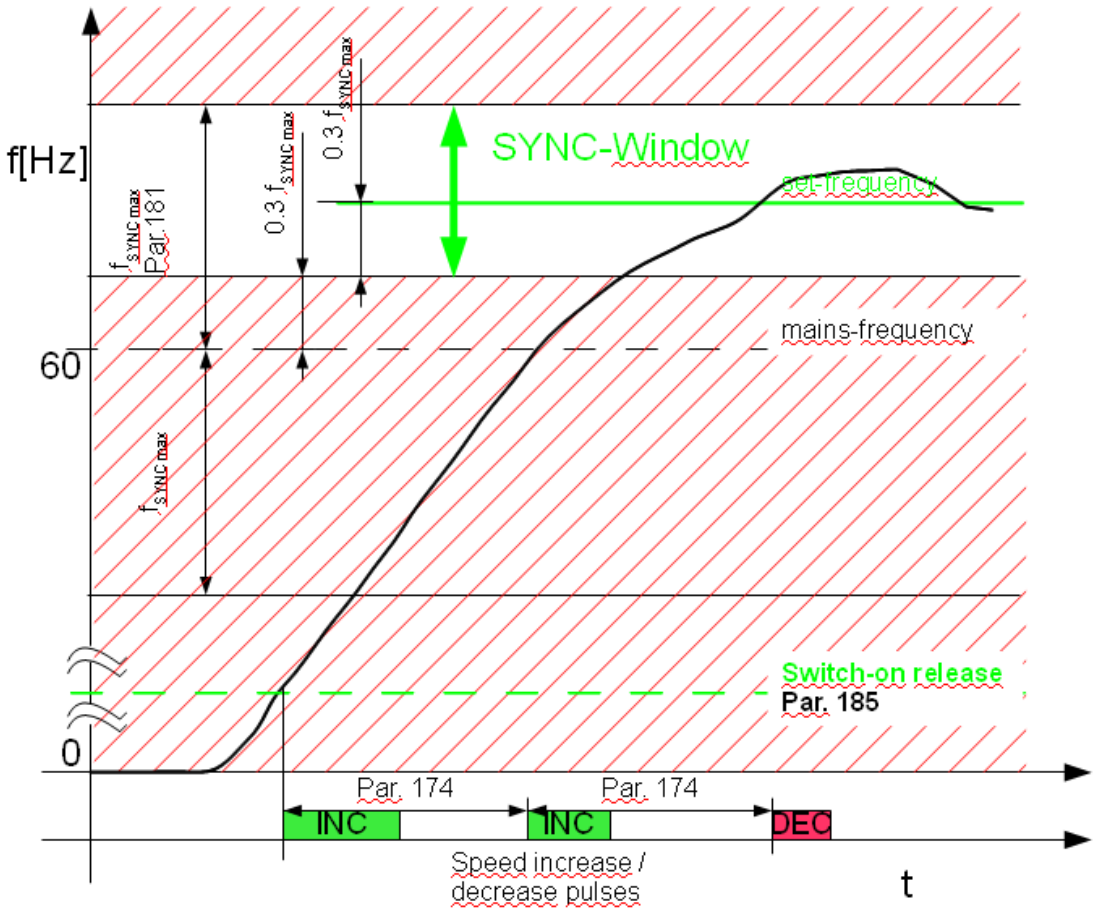


Diagram 7.6.1: Synchronization of a generator

The GPM is (nowadays) not giving pulses to the diesel's governor before passing the switch-on release limit (Par. 185). Parameter 185 defines the maximum deviation between generator frequency and mains frequency but the synchronization window is in fact smaller: GPM requires the synchronizing generator to be faster (30% of par. 185) than the operating generators, the controller's set-value is then 60% of par. 185 (+mains frequency!)

7.6.4 Synchronization Alarm

Synchronization is monitored, an alarm may be given if a certain synchronization time is exceeded. It is generally useful to cease synchronization by using the TRIP option in the function code! This enables the external or internal PMS to start another generator set. If the synchronization is not finished other generators may be blocked!

Synchronization failure [0.01s] *(87)*
Synchronization mode / Synchronization failure -Function *(147)*

7.6.5 Synchronization for Tiebreakers, Shaft-generators et al.

There are several devices, which can not influence frequencies on their own. They must influence diesel or turbo generators connected to adjacent subnets. By standard the set

frequency of the DOWN subnet is reduced by half of the allowed frequency deviation, while the UP subnets frequency is increased in the same way. The SYNC frequency controller *(Par. 192)* may reduce that difference, if >0.

Please keep in mind that frequency control of diesel generators also affects the behavior:

The MASTER controller (Tiebreaker, shaft-generator) is changing the set-frequency for the slave's (Diesel-generator's) frequency-controllers. Consider that here are two controllers in line, one delivering the set-value for the other: We have to be quite careful regarding the settings for the MASTER unit to avoid oscillations. It is recommended to adjust the DG's controllers first until load-sharing and frequency-control is working properly. After that MASTER units can be adjusted.

Diagram 7.6.2, p. 59, shows the cooperation between MASTER (Tiebreaker) and two SLAVE's, which should be in control of two gen-sets placed UP and DOWN[1]. Frequency control is symmetrical, frequency for UP subnet will normally be increased and frequency for the DOWN subnet will be decreased at the same time (using the same value)[2]. Therefore the effect is doubled, be careful[3]!

The same mechanism is used during unloading of tiebreakers and shaft-generators before disconnection!

Tiebreaker's and shaft-generator's GPM are only MASTER during synchronization and unloading. The MASTER-GPM's are sending their specific messages only in that case, there are no special CAN-messages during normal operation. MASTER and SLAVE-functionality is assigned dynamically, there is no such thing like a dedicated MASTER-device in the GEAPAS500-system.

It should be noted, that only one device per subnet is allowed to be MASTER at the same time and to send the respective messages[4], because only one frequency setting per subnet is possible!

1 REMEMBER: Power is counted positive by the Tiebreaker if coming from UP. Three-phase voltage measuring should be connected to the UP-busbar.
2 It is questionable whether it is better to affect only one subnet.
3 There is an inconsistency in case one of the busbars is linked to a shaft-generator or shore-connection. In that case control will be restricted to one busbar, the effect will be reduced.
4 The subnet-number is part of the CAN-identifier for the MASTER-data, so telegrams for the same subnet will bear exactly the same identifier. That is strictly forbidden under CAN for reason of collision handling!

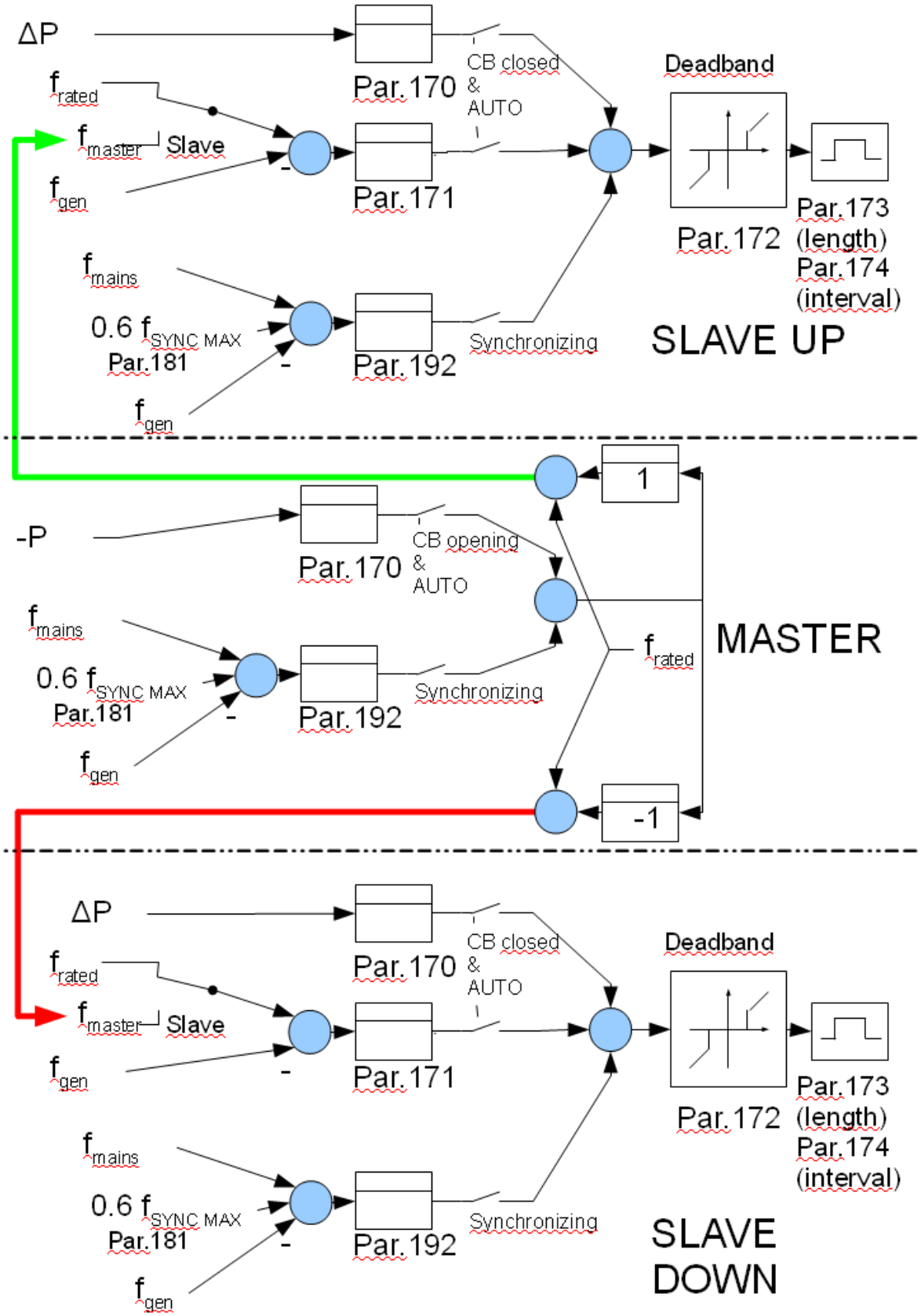


Diagram 7.6.2: Cooperation between GPM-controllers

UNIT 8 Loadsharing & Frequency-control

8.1 Preface

All generator's GPM-units are performing both frequency-control and loadsharing at the same time. There is no dedicated master-generator, which is solely responsible for keeping the frequency while other generator-sets are just responsible for loadsharing.

8.2 Subnet Number

C:\Dokumente und Einstellungen\HornUlr\Desktop\SchulungNEU\Subnet.odp

Subnet numbers are a very important part of the PMS concept. Subnet numbers will be calculated dynamically depending on breaker positions of busties. Subnet number will be displayed on page 6 (Identity, Generator No.) .

Subnet: A subnet is a piece of the network divided from other subnets by open breakers. The subnet owns an unique **subnet number**, which is calculated dynamically!

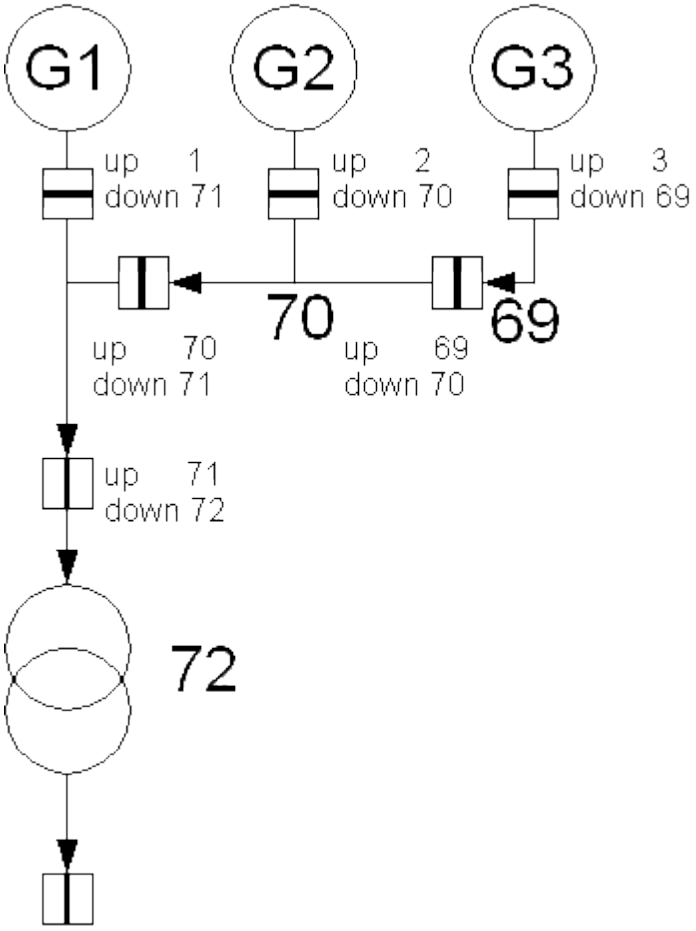
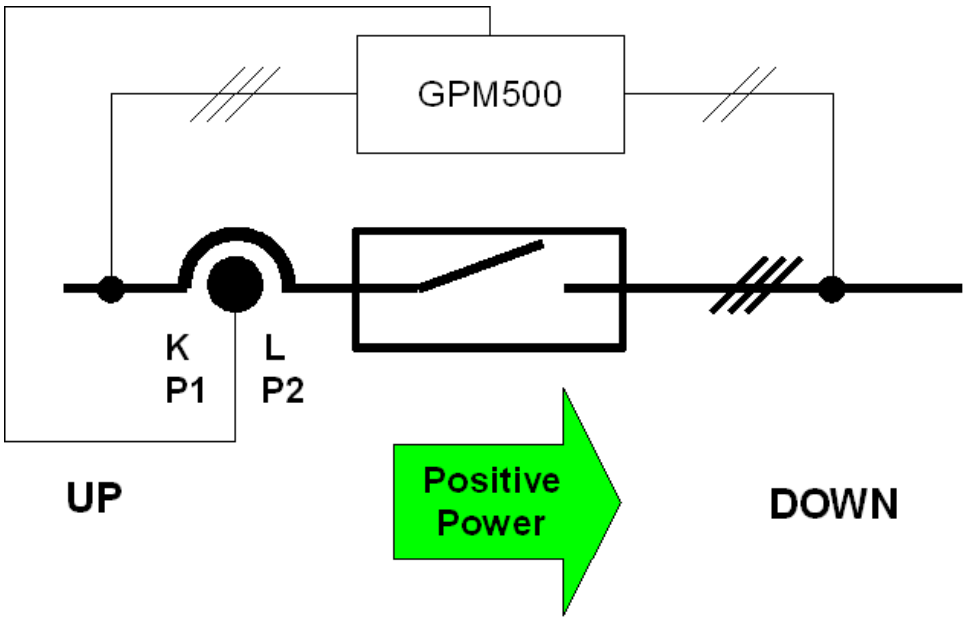


Diagram 8.2.1 Assignment of busbar numbers

Busbar is any part of the network, which may be separated by switches, breakers, contactors[1]. Busbar numbers should be assigned according to the following schemes and should be non-zero and NOT exceed 127. The terms **UP** and **DOWN** are describing the relation between a GPM and the adjacent busbars. (Power is indicated positive, if power is coming from the **UP**-system. Three-phase voltage measuring takes place always on the **UP**-side!)

1 A transformer with primary and secondary breaker is also a “busbar” in a topological sense!



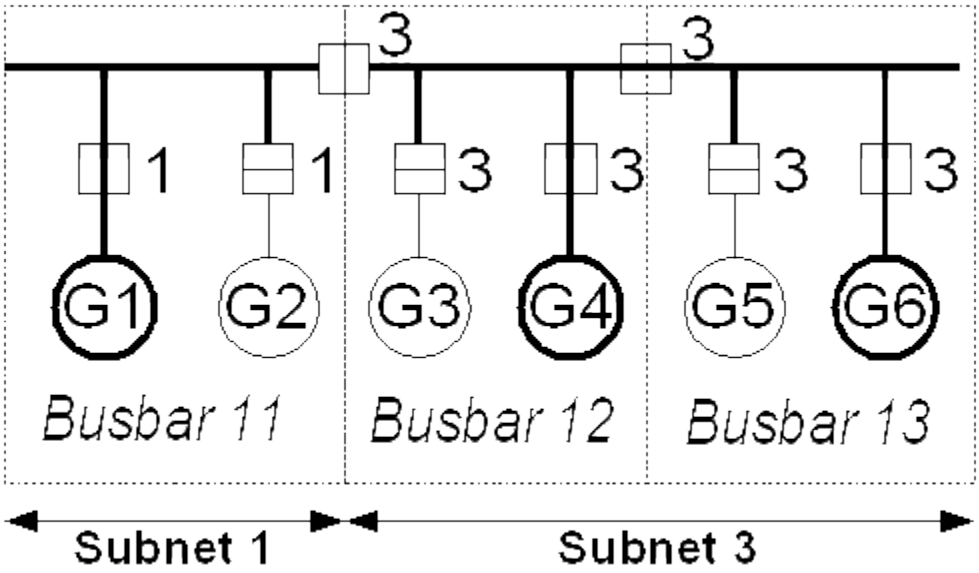
D 8.2.2: UP-DOWN numbering scheme

Calculation of **subnet numbers** uses the following rules:

1. **Subnet number** is the lowest generator number of the generators linked to the subnet[1]. Every GPM500 has one subnet number.
2. Only closed tiebreakers may transfer the subnet number to neighboring “busbars”!
3. Open tiebreakers do not transmit subnet numbers, they are taking the network number belonging to the side of three-phase voltage measurement (“Generator-side”)! This side is marked “UP” on the display[2].
4. Closed ring networks have to considered separately, ask SAM [3].

The following diagram shows calculation of subnet numbers in a network with three busbars:

1 Independent from the state of the breaker (closed, open, isolated, earthed)
2 Side of two-phase measurement is therefore **DOWN!**
3 There are some additional conditions, which should not be discussed here because of their complexity.



*D 8.2.3 Calculation of **subnet numbers***

8.3 Frequency Control

Mains frequency is measured by all generator GPM. The average of all frequency signals of a subnet is used as common actual value for all generator GPMs frequency controllers. Frequency controllers are simply of P-type.

Settings:

Frequency gain (%) *(171)*

8.4 Loadsharing Mechanism

Load is symmetrically shared between all generators (not shaftgenerators & shoreconnections) with a common subnet number (where AUTOMATIC mode is selected!!). An asymmetrical loadsharing may be forced by setting the “TOPLOAD” mode of the GPM500 for one generator. Generators in “TOPLOAD” mode try take a predefined part of their rated power/maximum power. After connection the generators load may be increased slowly (refer to Par.93 - “ramp %/s”). Generators are excluded from loadsharing until their full power is released.

The asymmetrical loadsharing is restricted by certain limits implemented in the GPM500: Other generator sets should not be pressed in underload or reverse power. Accidental use of “TOPLOAD” mode in solo operation should not lead to overfrequency.

Settings:

Load distribution: Amplification Power control[%] *(170)*

Topload (% of rated power) *(175)*

8.5 Loadsharing Shaftgenerator & Shoreconnection

Shaftgenerators and shoreconnections are not allowed to run in parallel with diesel generators for a longer time. So it can be assumed that no loadsharing is needed. And in fact shaftgenerators and shoreconnections are not included in loadsharing and their power controller is normally deactivated. But the shaftgenerator & shoreconnetion GPM use active power controllers during unloading (with setpoint zero!) which are increasing the set

frequency for other generators belonging to the subnet. So parameter 170 (power control) is not meaningless for shaftgenerators and shoreconnections but Par. 171 (frequency control) is without any relevance.

It should be kept in mind that Par. 170 of shaftgenerators GPM could not be seen independent from Par. 171 of the diesel generators GPM: **Power control of shaftgenerators is working through frequency control of diesel generators!**

Load distribution: Amplification Power control[%] *(170)*

Load distribution: Amplification Frequency control[%] *(171)*

8.6 Adjusting Controllers

Controllers are of P-type, they are just amplifying the difference-signals they get and are actuating the outputs via a pulse-generation logic. It is always assumed that the diesel's governors are performing the I-part (integration) of control. Controllers are operating between +1.0 and -1.0!

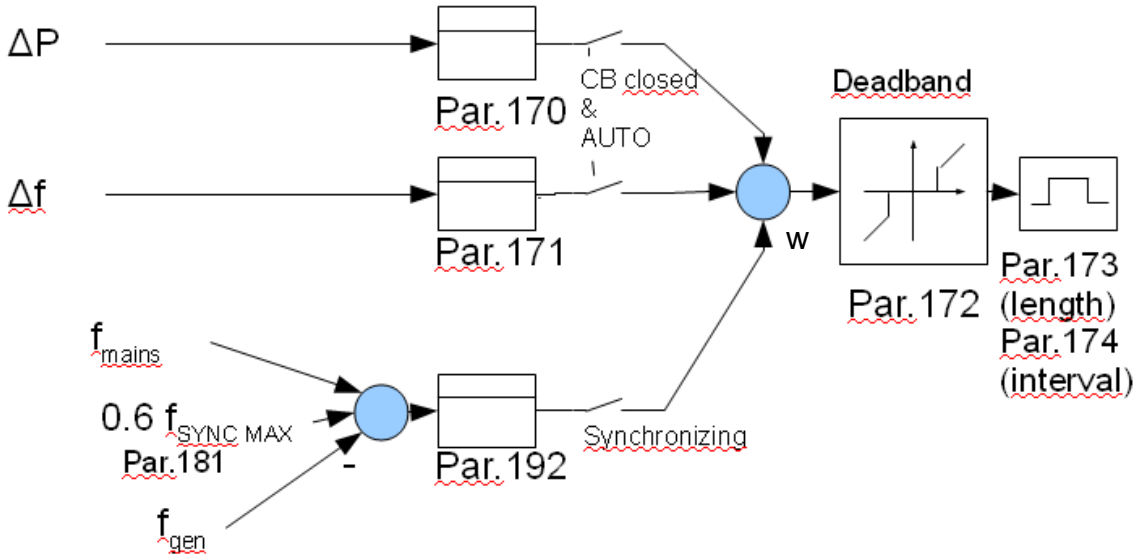


Diagram 8.6.1: GPM's controllers

Controllers mentioned in this unit are using a common deadband and a common pulse-generation unit. Deadband (Par. 172) is therefore no absolute setting regarding frequency and power deviations but is depending from gain-settings made in parameter 170, 171 & 192. A deadband of 1 % requires |w|>0.01 for any action!

Power-controllers deliver an output-signal of 1.0 to the pulse-generation unit using a gain of 100 % and a load-deviation of 100 %

The frequency-controller is non-linear, with gain = 100% we get an output-signal of ~1.0 with an frequency-deviation of about 1 Hz.

A special frequency-controller is provided for synchronizing: It delivers an output-signal of 1.0 if it's gain is adjusted to 100 % and frequency-deviation is 100 %. It should be taken

into account that the controller is only active during synchronizing (Refer to. 7.6)

Output-signals of all three controllers are added, the sum w must be out of the deadband to generate pulses. Pulses are generated with constant rate T_P defined by Par. 174. Length of pulses t_{pulse} is proportional to controller's signal w, but limited by the minimum pulse length T_{Pmin} :

$$t_{pulse} = max(w * (T_P - T_{Pmin}), T_{Pmin})$$

Please note that T_{Pmin} is (with older software) as well defining a minimum setting for the pulse-length as a minimum setting for the pause, the GPM is always making short breaks of T_{Pmin}. So an increased T_{Pmin} will there lead to reduced pulse-length with the same w:

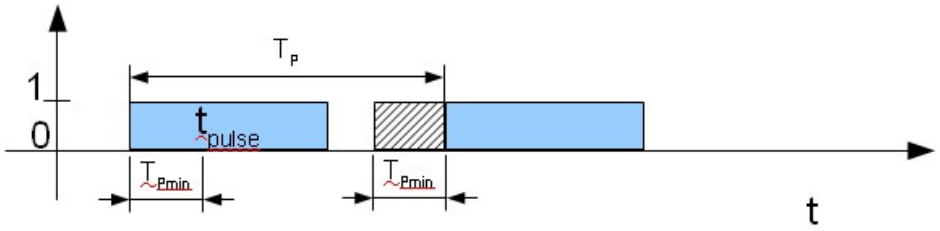


Diagram 8.6.2: Pulse generation (with definite pause)

With actual software (271.001020.G4 and later) a continuous signal can be generated in case of w=1. Pulse length is calculated before beginning the pulse, changes of w during pulse-time are without effect. So the controllers are in fact operating once per interval T_P:

$$t_{pulse} = max(w * T_P, T_{Pmin})$$

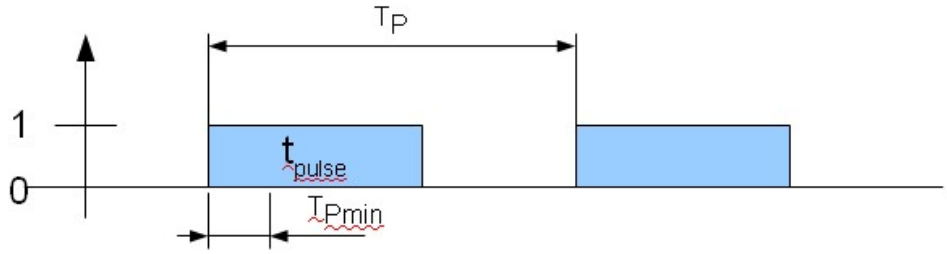


Diagram 8.6.3: Pulse generation without minimum pause

If the controller is reaching it's limit, pulse-length T_{pulse} becomes T_P and the GPM gives a permanent increase- or decrease-signal:

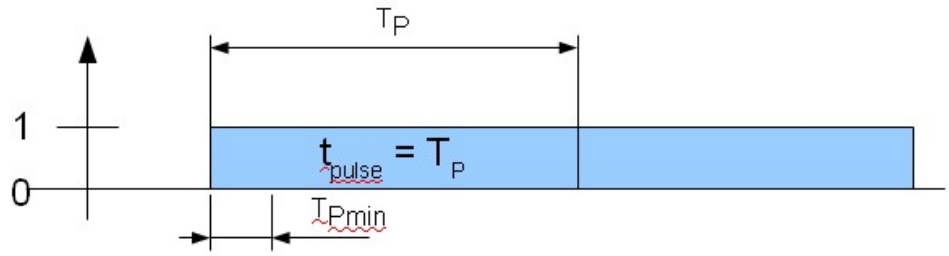


Diagram 8.6.4: Continous Signal

Reduction of T_P therefore enhances the controllers by reduction of the time lag.

Special problems are created by governors using discrete speed steps:

- If steps are “too big”, GPMs try to get in between and are increasing and decreasing set speed without getting to resIf pulse-length is too small to get the governor to the next step, the GPM permanently give pulses for the same direction without coming to an end. The GPM will give an alarm after 180 s (“Governor failure”) because it assumes a linebreak etc.

UNIT 9 PMS & BO-Start

9.1 Software Extensions PMS

Powermanagement Management System PMS is build up by the following components:

- Man Machine Interface MMI
- Software „Loadmonitor“
- Digital Inputs and Outputs DI DO (refer to 2.2.4)
- Analog Inputs (if necessary) (refer to 2.1.7.3)
- IAMCS functions

9.1.1 Man Machine Interface MMI (general)

The MMI of the Powermanagement Management System PMS uses two pages of the touch-panel BAT500. The first page (p. 35) is used to define start and stop limits for generator sets as well as start and stop delays, while the second page (p.36) allows definition of consumer-specific data. Page 35 is also used to visualize the actual state of the PMS (actual power reserve, requested power etc.). The mode of power-sharing may be influenced by using a MAXLOAD button on page 1 (start page). Load limit for the generator may be defined on page 2.

9.1.1.1 PMS-Page (P.33)

Maximum generator power of the subnet P_{max} is displayed in the left upper corner of the screen. The still available spare power of the subnet is displayed below (P_{res}). Actual generator power of the subnet P_{act} and requested spare power P_{req} (in kVA) (for consumers to be connected!) are displayed in addition. Consumer power is calculated in KVA because power consumption of consumers can be measured only as apparent power. The

actual power factor of the generator is used for correction.

In accordance with the common practice of making a load balance sheet apparent power is neglected to ease parameter setting.

The following parameters may be set by the user (yellow marked fields):

Power Management					**C H S 3C85**
P_{max}			2800 kW		ACTIVE/inactive int/EXT
					-------/Modes select
P_{res}			100 kW		**GEN 3 : Start in 23.8 s maneuver mode**
P **req**			**300 kVA**		
act			**2500 kW**		
No **Start1**	250	**kW**	30.0	**s**	
No **Start2**	100	**kW**	1.0	**s**	
No **Stop**	350	**kW**	30.0	**s**	
Navigation and Alarm-display					

Two power limits for start **(Start1, Start2)** must be defined. The particular device will be started, if spare power is below one of these limit for a time longer than the appropriate delay time. These delays are defined to avoid starting of generators in case of short power peaks.

Likewise a power limit for **Stop** of generators may be defined. It must be taken into account, that the defined spare power must be present **after** disconnection of the appropriate generator. If rated power of generators is not equal, a generator with lower rated power may be shut down before a larger generator without taking into account the respective priority.

Power management may be activated individually for any generator using the touch-panel field ACTIVE/inactive. It may make sense to exclude shaft generators from power management to optimize fuel consumption.

Touch-panel field „Mode select“ defines, whether a special DIO500 should be used for selection and display of PMS operation modes.

The next action to be taken by the PMS is indicated below the „Mode select“ field:

Generator No. – Action (Start/Stop) – Remaining time delay

Remark: Any generators GPM performs PMS calculations independently and will influence only its own generator set. Nevertheless all actions and all delay times of all generators

PMS are displayed here.

PMS operation modes are displayed on the touch-panel:

The operation mode selected for the subnet is indicated by the text “No” above “Start1” and “Start2” in case of operation mode “No DG START” and above “Stop” in case of operation mode “No DG STOP”. Maneuver mode is indicated by an appropriate text.

9.1.1.2 Consumer Page (P.34)

This page allows definition of spare power to be reserved for large consumers (P_{req}). A second parameter allows definition of a current transformer ratio, if the apparent power taken by the respective consumer should be measured. Any GPM500 operates up to 6 consumers. PMS functions are distributed over all GPM, so large consumers should be assigned to a GPM which is connected to the same busbar as the consumer itself.

Power Management				
Cons 1	560	**kVA**	CT ratio DIF500 IE3: **9,10**	**A: 1 A**
Cons 2	1500	**kVA**	CT ratio DIF500 IE2: **15,16**	**A: 1 A**
Cons 3	360	**kVA**	CT ratio DIF500 IE1: **13,14**	**A: 1 A**
Cons 4	780	**kVA**	CT ratio DIF500 ID3: **5,6**	**A: 1 A**
Cons 5	920	**kVA**	CT ratio DIF500 ID2: **3,4**	**A: 1 A**
Cons 6	1700	**kVA**	CT ratio DIF500 ID1: **1,2**	**A: 1 A**
Navigation and Alarm-display				

9.1.1.3 Start Page / HOME (P.1)

Start priority may be influenced by touch-buttons „P+“ and „P-“. Values between 0 and 12 may be selected. This attribute of priority is superior to others.
Touch-button “Topload” enables asymmetric power sharing, the respective generator to loaded with 80 % of its rated power if possible without bringing other gen-sets in underload.

9.1.1.4 Measured Values (P.2)

Available power of an generator may be reduced to values between 100 % and 0 % of the respective rated power. PMS uses only the defined available power for its calculations, power is shared accordingly.

9.1.1.5 Software PMS

PMS software is integrated in all GPM500. Start and stop commands are given only for the GPM’s respective generator set, so PMS calculation had to be performed in all GPM in

parallel.

Connection of large consumers is executed in several steps:

1. Power for a large consumer is requested by setting the appropriate Digital Input (DI). The GPM500 requests the required spare power via XPM-Telegram. The request may be indicated by a flashing light operated by a Digital Output. The DO for consumer release is kept open for 2 seconds anyway to provide time for calculations and data exchange.
2. All GPM500 belonging to a subnet are calculating the total requested spare power for the respective subnet ...
3. ... and are calculating the actual spare power from the GPM-Telegrams.
4. The generators GPM check whether any start condition is met. If so, a locking bit is set in the XPM-telegram to exclude all consumer connections in the subnet. If no locking bit is set in 2 seconds after request, DO´s for consumer release are closed.
5. The generator set with the highest start priority (lowest priority figure) is started. (A stopping or after-running generator is although preferred without reference to its priority!)
6. It is checked, whether further start conditions are met after adding the power of the starting generators P_{start} to the spare power. If so, additional generator sets are started and locking bit remains set.
7. If no start condition is met, spare power is sufficient, locking bits will be reset and consumer connection is released.

Sequence for generator stop is similar:

1. Generators GPM are checking, whether stop condition is met. If so, a marker bit is set to inform other GPM about this fact.
2. Generators GPM compare their priorities with each other, the GPM with the highest stop priority (highest priority figure) is stopped first
3. Power of stopping generator sets P_{stopp} is subtracted in the calculation of spare power, If further stop conditions are met, additional generator sets will be stopped according to their respective priority as long as no stop condition is met anymore.

9.1.1.6 Functions of IAMCS

Commands may be written in Reg. 40029 using the following command codes. Command extension should be zero, if not used!

Command	**Address Code (High Byte Reg.40029) / Command Code**	**Extension (Reg. 40028)**	**Remark**
START	$0069	$0000	Connection command for not-starting devices like transformers or for generator sets started by external systems

STOP	$006A	$0000	Disconnection command for not-stopping devices like transformers or for generator sets stopped by external systems
Set PRIO	$xx66	$0000	Set priority to xx
Dec PRIO	$0067	$0000	Decrease priority by one
Inc PRIO	$0068	$0000	Increase priority by one
Toggle TOPLOAD	$0074	$0000	Change loadsharing mode
Set TOPLOAD	$006B	$0000	Set loadsharing to TOPLOAD mode
Reset TOPLOAD	$006C	$0000	Finish TOPLOAD mode
Set NO DG STOP	$0070	$0000	Force operation mode NO DG STOP for this subnet
Reset NO DG STOP	$0071		Release operation mode NO DG STOP request, mode may be remain selected for this subnet because other members request NO DG STOP!
Set NO DG START	$006E	$0000	Force operation mode NO DG STOP for this subnet
Reset NO DG START	$006F		Release operation mode NO DG START request, mode may be remain selected for this subnet because other members request NO DG START!
Set MANOEVER	$0072	$0000	Force operation mode MANOEVER for this subnet
Reset MANOEVER	$0073	$0000	Release operation mode MANOEVER request, mode may be remain selected for this subnet because other members request MANOEVER!
~~**ALARM ACKNOW-LEDGE**~~	~~$0065~~	~~$0000~~	**Not for REMOTE use, acknowledges all alarms visible on the BAT500s alarm page!**
ALARM x ACKNOW-LEDGE	$xx6D	$0000	Acknowledges an individual alarm **xx, to be used by external components**
SET SPARE POWER	$0077	Power in kW	Requests an additional spare power
SET MAX POWER	$0078	Power in 0.1 %	Chief limitation
SET TOPLOAD POWER	$0079	Power in 0.1 %	Setting of Topload power
~~**LIFEGUARD x**~~	~~$xx7D~~	~~$0000~~	~~xx to be changed with every new message to prove, that external panel is "**alive**"~~

Mode selection is OR-linked with hardware inputs. Selection of „No DG Stop“ by hardware input can not be overruled by telegram!

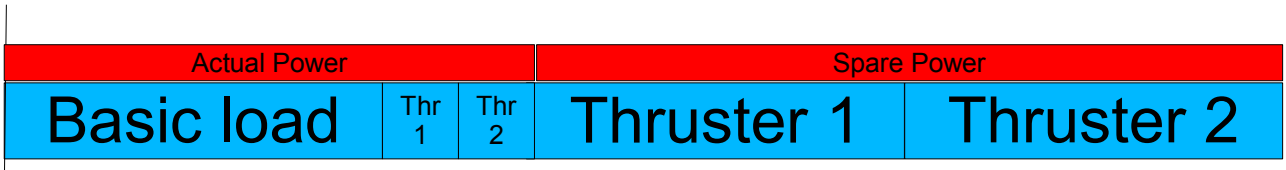
9.2 Power Management System PMS

The Power Management System (short PMS) of GPM500 is designed for cooperation with external systems. Nevertheless GPM500 is capable to perform tasks like symmetrical power sharing, load-dependent start and stop of generators and loadmonitoring. Up to now 63 GPM500, including 12 generators[1], may operate together using one redundant data-bus (CAN1 & CAN2). (Refer to 5.1.1) The PMS requires use of unique device numbers for all GPM500 linked to one redundant bus. Generator numbers should be limited to the range 1 to 12, generally device numbers should be limited to 1 to 63!

9.2.1 Spare Power & Loadmonitor

Spare power is calculated for every subnet individually by every GPM500. Depending on the spare power, generator sets are started and stopped automatically. Spare power is checked before connecting large consumers, if needed an additional gen-set will be started and synchronized, before connection of this consumer is allowed. The loadmonitor is designed for maximum 6 consumers per GPM500. A rated power may be defined for any of these consumers and a current transformer ratio, if actual load should be measured. **It should be taken into account, that generators in MANUAL mode do not provide any spare power[2].**

Spare power calculation can be continued after connection of the Consumer, the spare power request will be reduced to the difference of rated and actual power. If e.g. a thruster runs idle with about 30% of its rated power, a power request of 70 % is maintained. This mechanism requires building separate spare power for any additional major consumer and increases safety with consumers which have a large power difference between full load and idle operation[3].



Structure of load management:

- **Calculation Subnet number:** Any GPM500 calculates its subnet number in such a way, that all consumers (transformers, motors) and producers carry a common subnet number. The sum of generator powers and the sum of spare powers (Total Spare

1 Generator numbers 1 to 12 are allowed. Request for more, if needed! (2010: → 16)
2 That may cause start of an additional generator, if a generators GPM is switched to MANUAL mode!
3 This is typical for bow and stern thrusters, they need just a small portion of their rated power while running idle. The requested spare power may needed suddenly for all thrusters in case of a maneuver

Power TSP) are calculated for devices belonging to one subnet. Subnet number is the lowest generator number belonging to the subnet and can therefore not be a consumer.

- **Spare Power Request:** Any GPM500 reports the requested spare power for the consumers controlled by itself. The requested spare power is the difference between rated apparent power and actual apparent power. It is not important, whether the consumer is controlled by an individual GPM500, as it is the case in medium voltage systems, or if it is controlled by a generators or tiebreakers GPM500. Special conditions like “NO DIESEL STOP” may be set with any of the devices belonging to a subnet.
- **Total Spare Power:** GPM500 are calculating the TSP and the total requested spare power by evaluating the reports of their fellow GPM500.
- **Comparison with Power threshold:** GPM500 of generators calculate the difference between TSP and requested spare power and check whether their individual start and stop limits are affected. If an individual start or stop condition is met, this is reported to the other generators GPM belonging to the subnet.
- **Comparison of Start and Stop priorities:** Generators GPM, whose start or stop conditions are met, compare their respective priorities. Generator with the actually highest priority will act accordingly. Priority is calculated using Generator No. (lowest influence), Operating Hours Equivalent OHE and generators priority parameter (highest influence). Stopping generators start priority is increased to guarantee quick reaction in case of sudden power demands.

Start- and stop-limits may be assigned individually to all the generators. If generators of different rated power are installed, a smaller generator may be switched off first in spite of its lower stop priority. The smaller generator may be the only one, whose stop condition is met **and priorities of generators are only compared, if their individual start/stop condition is met!**

The use of generators of different type and rated values leads logically to the definition of start and stop limits in the unit kW.

It must taken into account, that several generators may be started at the same time to provide the total requested power. The GPM500 check, whether the rated power off running generators plus rated power of starting generators met their start condition. If so, generator sets would be started until no start condition is met. Synchronizing may yet be delayed until devices with lower device numbers are connected. So generators may be connected at short intervals.

Consumer connection though will released first, if enough generators are connected.

On the other hand stopping generator sets will not be taken into account regarding the spare power calculation.

A generator set will be disconnected, if remaining power is sufficient. The following diagram shows the connections explained:

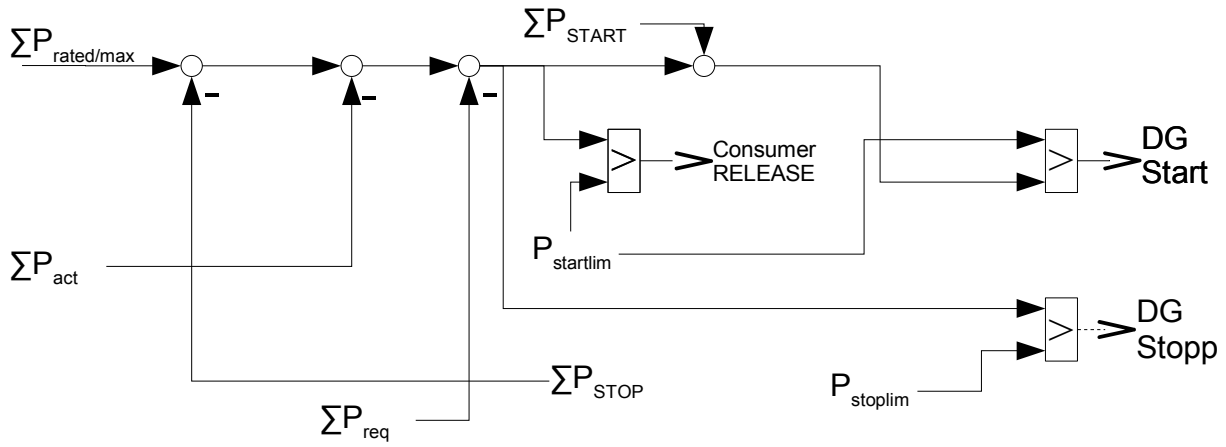


Diagram 9.2.1Description of start, stop and consumer release conditions

START: A generator set will be started , if sum of rated/max power $\sum P_{rated/max}$ of working generators plus sum of rated/max power of starting generators $\sum P_{START}$ minus actual $\sum P_{act}$ and requested ($\sum P_{req}$) load is lower than the set start power limit $P_{startlim}$. Two of these limits with respective start delays are implemented.

STOP: A generator set will be stopped, if surplus power minus rated/max power of the calculating generator itself exceeds a second limit $P_{stoplim}$!

The power management uses three operational modes :

- „NO DIESEL START“ (permanent signal required, no pulse)
- „NO DIESEL STOP“ (permanent signal required, no pulse)
- „maneuver MODE“ (permanent signal required, no pulse)

These operation modes may be chosen with any GPM500 of the respective subnet.

- „NO DIESEL START“ means, that no gen-sets are started by the PMS. (Remark: Blackout-start is not inhibited by choosing this mode!)
- „NO DIESEL STOP“ means, that no generator sets are stopped by the PMS, e.g. while trading in coastal waters.
- „maneuver MODE“ activates an additional power request (one generator power)

9.3 Blackout-Start

In case of blackout at the busbar a diesel-generator set is started automatically by the GPM500 and connected automatically after switch-on release is given.

It is very important to use a second criterion together with missing busbar voltage. The GPM500 uses an additional digital input, which must be closed in case of blackout. Furthermore it is checked via the redundant CANbus (CAN1 & CAN2), whether other generator breakers are closed.

Blackout-Start may only be activated *(Par. 189, Bit 0=1)*, if it is sure, that only one connection may take place! Start-priority will be compared, if devices are connected by CANbus.

Settings:

Start delay *(Par.190)*

Modes *(Par. 189, Bit 0)*

9.4 Blackout-Prevention

The GPM500's PMS has a major and sometimes surprising side-effect: GPM for generators and tiebreakers try to maintain supply for all parts of the network while in AUTO mode. This is also the case if PMS is set inactive by setting Par. 189, Bit 2 to zero! The GPM are not only preventing blackout by avoiding disconnection of generators but are also providing sufficient spare-power for all parts.

Nevertheless we have to cover situations, where parts of the network must encounter a blackout:

- Two switchboards are connected via transfer-line cable, which is protected by one transfer-line breaker in each switchboard. If both switchboards are supplied by a sufficient number of generators, one transfer-line breaker can be unloaded and finally opened by its GPM. The other transfer-line breaker remains blocked, because its GPM tries to avoid a blackout on the transfer-line.
- All breakers of a medium-voltage switchboard are open, except one generator-breaker. The respective GPM will refrain from opening this last generator-breaker to avoid blackout on the medium-voltage busbar.

Both problems may be solved by setting Par. 189, Bit 7! In case of the medium-voltage generator we may need additional settings to avoid blackout-start:

- A low-voltage generator's (or shore-connection's) GPM needs setting of Par.189, Bit 8 to send a “no-blackout” message, while
- the medium-voltage generator's GPM needs Par. 189, Bit 9 to suppress it's local blackout-start as long as the low-voltage system is supplied.

Another problem is not yet solved: Some bus-bars may be without supply in certain operation modes! Some vessels use a special bus-bar (switchboard) for the shaft-generator which is either feeding the main switchboard or a set of thrusters. The shaft-generator's bus-bar needs no supply, if the shaft-generator is not operating, so a planned-blackout mechanism may be helpful. Future GPMs will allow a planned blackout for bus-bars with numbers greater or equal 100. Please avoid use of these numbers in future projects, if it is not intended to allow blackout for these bus-bars.

UNIT 10 Parametrization

10.1 Access via Touch-panel

Most parameters may be changed using the touch-panel Some parameters of experimental or very special nature may be accessible via parameter tool only. Please familiarize with the use of the so-called function-codes FC: Every alarm owns a parameter which allows to determine the function of the alarm by setting the appropriate bits. The touch-panel allows using of a hex-code instead of filling in the bits individually!

10.2 Access via Parameter Tool

10.2.1 Introduction

Setting of parameters may be done using the touchscreen. That may be annoying

because many settings are identical for many devices. So a tool is provided, which allows editing, download and upload of parameters via serial interface. The parameter tool includes an online help (HTML), which gives information for all parameters.

10.2.2 Starting the Parameter Tool

The parameter tool as an simple .exe-file may be started without any installing. The folder PARA_HTM should be in the same path as Para1.exe to make the online help accessible.

Before performing any operation, a parameter file *.vtx must be loaded. (File/Load):

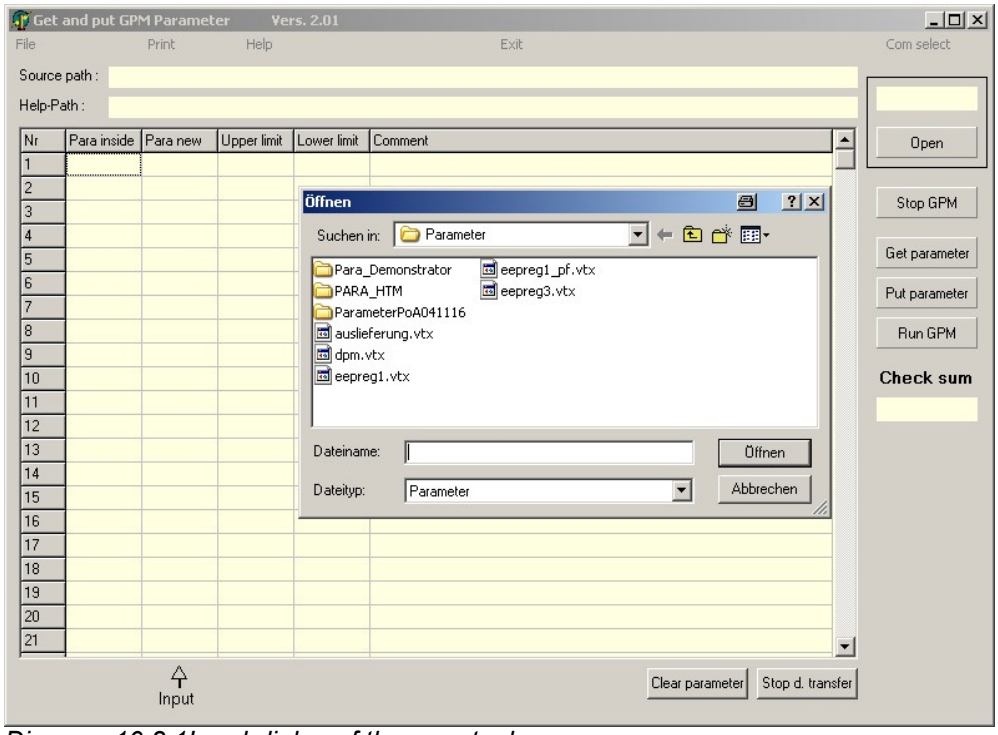


Diagram 10.2.1Load-dialog of the para tool

10.2.3 Editing Parameters

The parameters in the *.vtx-file are displayed in the “Para new”-column. They may be edited either directly after left-clicking in the respective field or by using a bit-mask field after right-clicking into the field. **The ENTER button should be used after editing the parameter directly.**

Parameter file will be changed after (File/Save)! The online help will be accessed after clicking into the respective “Comment”-field.

10.2.4 Online Operation

Parameters inside the GPM500 may be accessed via serial interface:

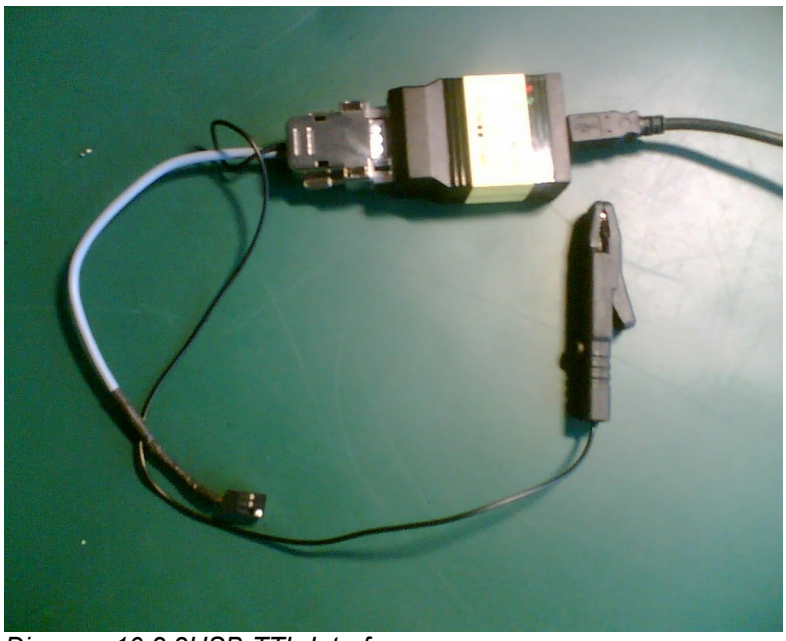


Diagram 10.2.2USB-TTL-Interface

The tiny plug must be fitted into the hole in ZKG500 cover. The plugs “nose” or another special mark should be directed to the “ZKG500” text on the cover.

The serial interface can be activated after installing the driver (4N-GX_USB-RSxx_TTYx_Win-Driver.zip).

The appropriate COM-Port had to be selected and opened:

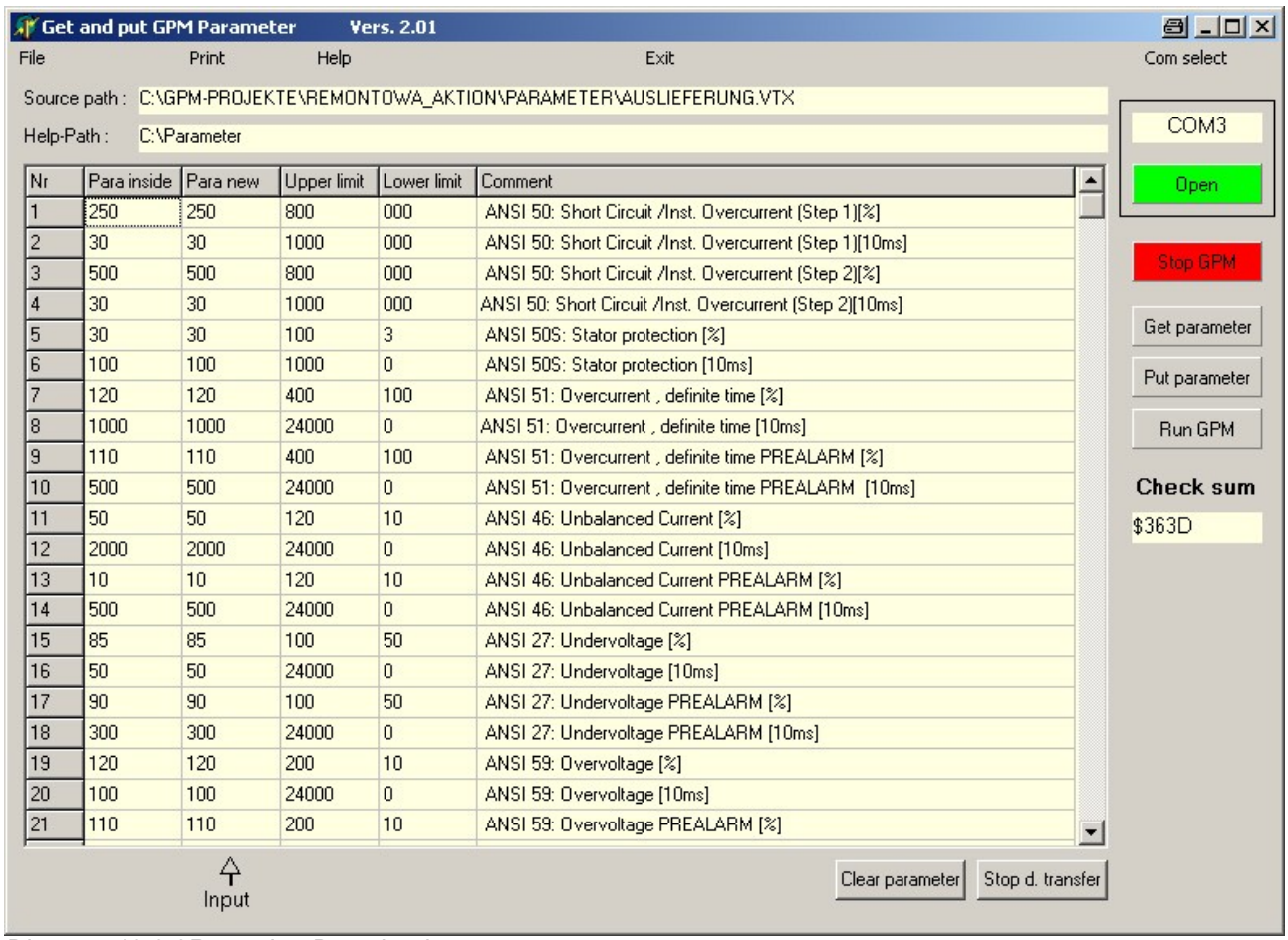


Diagram 10.2.3Preparing Download

In case of download to the GPM500 the GPM500 must be stopped (“Stop GPM”). After downloading (“Put parameter”) the GPM500 can be started again by using “Run GPM”. Before downloading the parameters are saved in the *.vtx-file to safeguard data integrity.

In case of parameter upload the GPM500 must not be stopped. The uploaded parameters are presented in the first column “Para inside”. These parameters may be copied in the “Parameter new” row by using the Move-command in the “File”-menu. The contents of the “Parameter new” column may be saved by using the “Save”- and “Save as”-commands in the “File”-menu.

UNIT 11 Training 2: PMS & Parametrization

UNIT 12 I/O & Wiring

12.1 Blackout-Chain

As mentioned in 7.2, blackout-detection is using three independent criteria. One is activation of digital input DI 8 of the second DIO500 (DIO500#2:16). IT IS RECOMMENDED to make a hard-wired connection to all other generator breakers to

make sure that no other generator is on line!

The respective hard-ware logic may become quite complex by inclusion of tiebreakers!

Consumers have blackout on the DOWN-side anyway, so the DI8 can and must be bridged.

Tiebreakers need activation of the DI8, second DIO500, if either UP- or DOWN side are blackout (or both!).

12.2 Double power supply

The GPM500 is designed for use of two power supplies (24 V DC from automation battery , 19 V AC 3~ via special transformer fed from generator voltage)! This allows building up the ships mains after blackout by just starting a generator manually!

If a second DC source is used instead of the 19 V AC system the three 19 V inputs should be connected together to +24V (to avoid heating the rectifiers diodes) while the minus wires of both supplies should be connected.

Both voltages can be monitored by the GPM!

Don't use the special transformer to deliver the voltage signals for the Transducer units TRV50x!

12.3 USE of the NEG outputs

24V+ for any digital input should be provided by outputs of the NEG50x (or 510, if present):

- The NEG500 contains a special filter, which should not be bypassed for EMC reasons
- THE NEG500 contains an ultra-capacitor, which maintains supply of the GPM500 modules during short blackouts on the 24 V DC and 19 V AC supply (e.g. during short-circuit). Otherwise DI activated by external sources may be deactivated wrongly and cause malfunction of the GPM (e.g. trip by stator protection due to missing breaker feedback)!
- NEG outputs are fed by both power supplies!

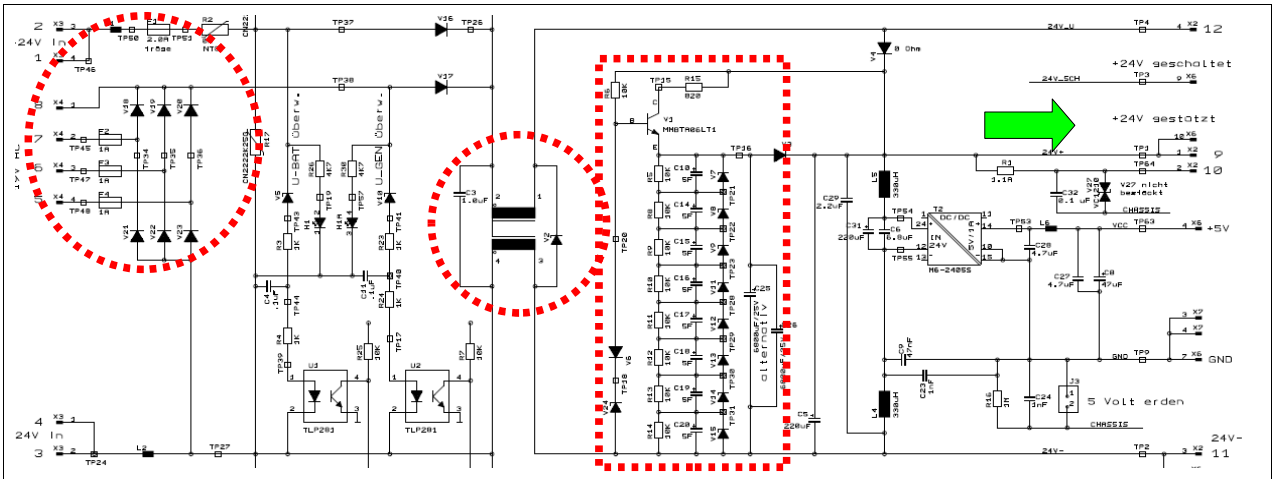


Diagram 12.3.1: NEG501: Reasons for use of internal 24-V-supply

12.4 Undervoltage Coil support USS500

If breakers are controlled by an undervoltage coil (recommended!), a short-circuit may cause opening of all breakers immediately. So protection devices are unable to disconnect the faulty part of the network because the current is reduced before the trip delay time of is reached.

The USS500 provides voltage for the undervoltage coil during such interruptions of supply. It contains two rectifiers of B6-type and a capacitor. The special GPM-transformer supplies also the USS500.

Don't use the special transformer to deliver the voltage signals for the Transducer units TRV50x!

12.5 Ground-voltage

The GPM500 is capable of measuring the ground voltage using an open-delta coil in the voltage transformer.

12.6 Shielding & Terminals

Bus cables should be twisted-pair, shield should be solidly grounded. CAT6 cable recommended.

Bus cables should be connected directly to the ZKG500, respective NEG500 (CAN4). No terminals should be used in between.

Avoid branching the bus cable with respect to reflections.

Buses should be terminated using the internal resistors in the GPM's modules.

12.7 Free-wheeling diodes

All relay's coils should be equipped with diodes to avoid creation of sparks inside the GPM. With AC coils RC-elements should be used.

Please do the same for governor motors!

12.8 Blackout-Start for NON-generators

Please take into account, that starting and connecting the main generators is not in any case sufficient for automatic recovery of supply. Blackout-start for transformers may be needed as well.

12.9 Tripping using the SLE (SLE500:7,8)

The GPM500 provides a TRIPPED signal on DIO500#1, DO3. This is not designed for controlling the breaker but just for indication. The output SLE500:7,8 should be used instead. Two reasons:

- Short-circuit protection is implemented inside the SLE500, so the DIO500-output is delayed
- The hardware backup-protection inside the SLE is only operating SLE500:7,8

12.10 BAT supply

Standard drawings show the BAT's supply derived from external 24 V (via DCC). It may be useful to connect the DCC to outputs of the NEG 501(Terminal 12!). By that measure we achieve a backed-up supply for the panel (refer to Diagram 12.3.1)!

UNIT 13 Testing

DAY 4

UNIT 14 Programming

14.1 Software Description

14.1.1 SPS, Graphic-Editor & Assembler

14.1.2 Software Structure ZKG500

Software may be adapted (in certain limits) by designer or commissioning engineer. Some parts should not be touched anyway for safety reasons. GPM500´s concept does not exclude all improper software modifications, so the programmer must have a sufficient knowledge of GPM500´s software structure[1]:

- BAT500 telegrams

14.1.2.1 Cycles & processes

The GPM500s software is not monolithic but is divided in processes. Any process as an independent software unit had to be assigned to a cycle to be executed. Moving a process to another cycle with another cycle time means changing the repetition rate of the process and hence its behavior

1 SAM-MBA3 can´t take any responsibility for software changes made by external programmers.

14.1.2.2 Register, INT & BOOL

GPM500 uses three types of data:

Data type	Description	Colors used by GPE	
		Edit-mode	Online / simulation
(LONG) INT[1]	4 Byte, to be declared, identified by name	yellow and pink	yellow and pink
BOOL	4 Byte, to be declared, identified by name	blue	red=FALSE green=TRUE
REGISTER	2 Byte, given, identified by number 0 -1999		

Processes use INT and BOOL data formats for their calculations. Protection software uses INT as an 32-bit field. The interpretation of INT is depending from the context:

- 2147483647 (=$7FFFFFFF) ... 0 (=$00000000) ... -2147483647 (=$80000001) **pink**
- ~1.0 (=$7FFFFFFF) ... 0 (=$00000000) ... ~-1.0 (=$80000001) **yellow**
- 180° ... 0° ... -180° **yellow**

The first interpretation is used when calculating spare power etc., the second interpretation is used by the protection functions.

It must be recognized, that any external communication either via Modbus or via CAN must use registers. Telegram components need to reference registers. All information which should leave or enter the GPM500 must be stored in a register[2]. So the register reference is an important document for the programmer: Any registers content should be documented in a table (e.g. Excel-sheet!)

Registers range from 0 to 1999 using the following structure:

Type	**Register No.**	**Parameter No.**	**Accessible via**	
EEPROM	0 - 191	1 - 192	Panel & Para1.exe	
EEPROM	192 - 199	193 - 200	Panel only	
RAM	200 - 1119		Not accessible	
		MODBUS Adr.		
RAM	1120 - 1146	40001 - 40027 (phys. 0) (26)	MODBUS	GPM data (mirror)
RAM	1147 1147	40028 - 40028	MODBUS	Extension
RAM	1148 1148	40029 - 40029	MODBUS	Command

1 There is only a 4 Byte Integer, so LONG makes no sense!
2 Except digital and analog inputs and outputs by DIO500, GOV500, NEG500 and ZKG500. However, data from SLE500 is stored in registers.

RAM	1149	1157	40030 - 40048	MODBUS	GPM data (mirror)
RAM	1158	1999		Not accessible	

14.1.2.3 Design

If registers must be used for any external communication (even for the BAT500), commands for type conversions are very important.

Values measured by the SLE500 are found in registers 200-248, they hat to be transformed to INT. The process *Normierung* is used for that transformation. Almost any signal is transformed in such a way that the rated value is represented by $10000000 = 0.125! The INT-type signals bear names like UGEN12_0125 to remind the programmer of that definition.

The process *Normierung* has the the second task of transforming these signals into 2-byte signals which may fit into registers for visualization Data is represented in V,A,kW here.

The process *Normierung_FIX* provides (semi-constant[1]) factors used in *Normierung.* This is done to reduce computation time, because *Normierung_FIX* is placed in a special cycle with a cycle time of 2 seconds.

Protection processes rely on INT values provided by *Normierung*. The protection processes can use standardized functions because any process data is represented according to the scheme “rated value=0.125=$10000000”.

14.1.2.4 Protection Chain

1 Only changed, when parameters are changed.

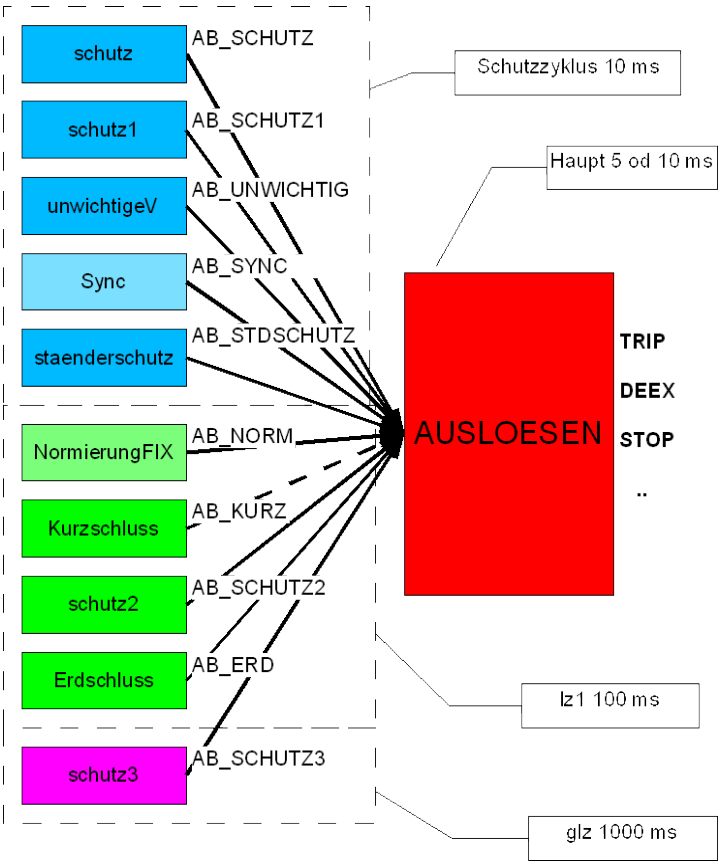


Diagram 14.1.1Protection functions

Several (protection) processes are running to execute protection functions. Each process provides an analog value **AB_xxx** as an output. Any bit of this value defines a certain reaction in case of alarm (refer to 6.3). The OR-type association of these signals makes sure that the most restrictive reaction is chosen if several alarms occur at the same time.

The signals **AB_xxx** of the protection processes are combined in process **AUSLOESEN**[1]**.** The combined signal is decoded by macro **Sammelalarm**[2]**.** The appropriate digital outputs are set by this macro.

14.1.2.5 Parameter Handling

The GPM500s behavior is influenced by parameters. Parameters are stored in registers 0 -199 (referred to as Par. 1 to 200). A parameter tool may be used to change these parameters. The parameter tool allows

- Upload (reading parameters from GPM500)
- Download (writing parameters to GPM500)
- Saving & Loading to/from (hard)disk
- Editing

An online help provides documentation (HTML) for every parameter and links between parameter descriptions!

1 German for “**TRIP**”
2 German for “common alarm”

14.2 Integrated Development Environment IDE

Software for the GPM500 may be edited and designed using the GPM500 IDE: The IDE may be started without prior installation.

Remark: No BLANKS should be used in names of files and folders in the IDE.

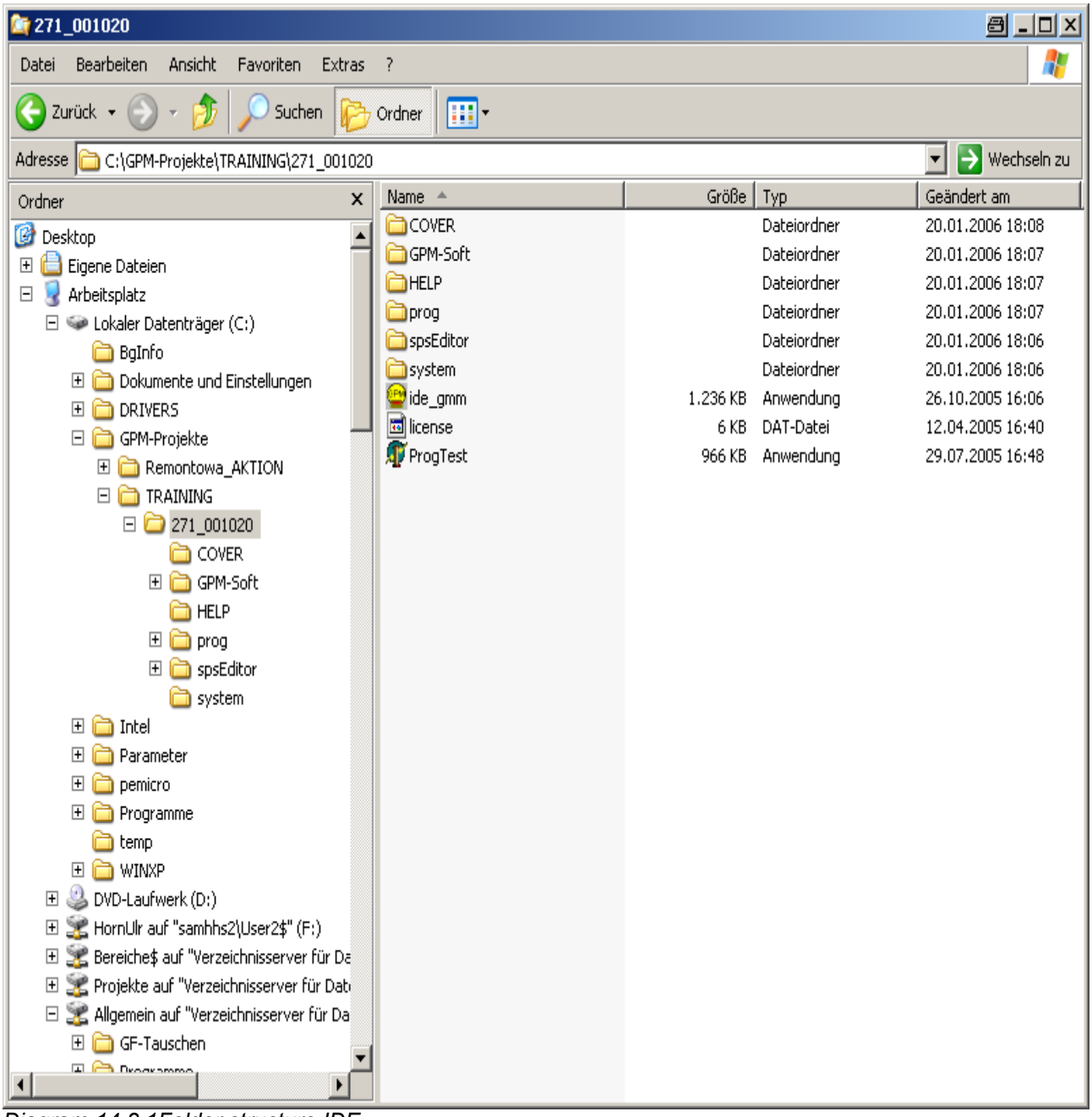


Diagram 14.2.1Folder structure IDE

The IDE may be simply started by double-clicking the “Ide_gmm”-icon. Software is mostly delivered in a folder named 271_0010xx,index. *(Often zipped for practical purposes!).* The editable software is placed in the folder “GPM-Soft”, the other folders contain tools.

After starting the IDE, a project must be selected, mostly there is only one (“GPM-Soft”)! The following screen opens:

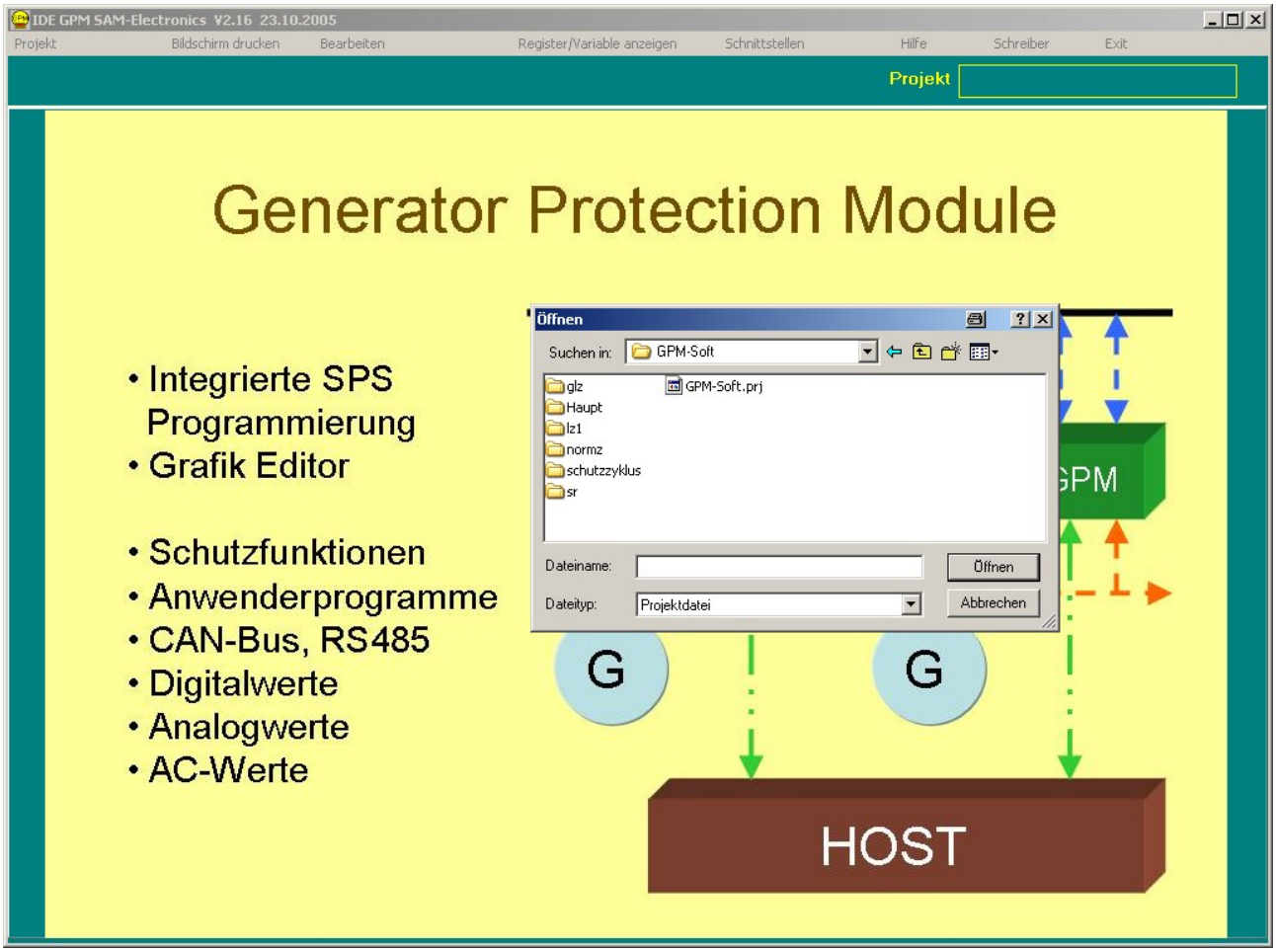


Diagram 14.2.2Selection of a Project

The main page of the IDE opens:

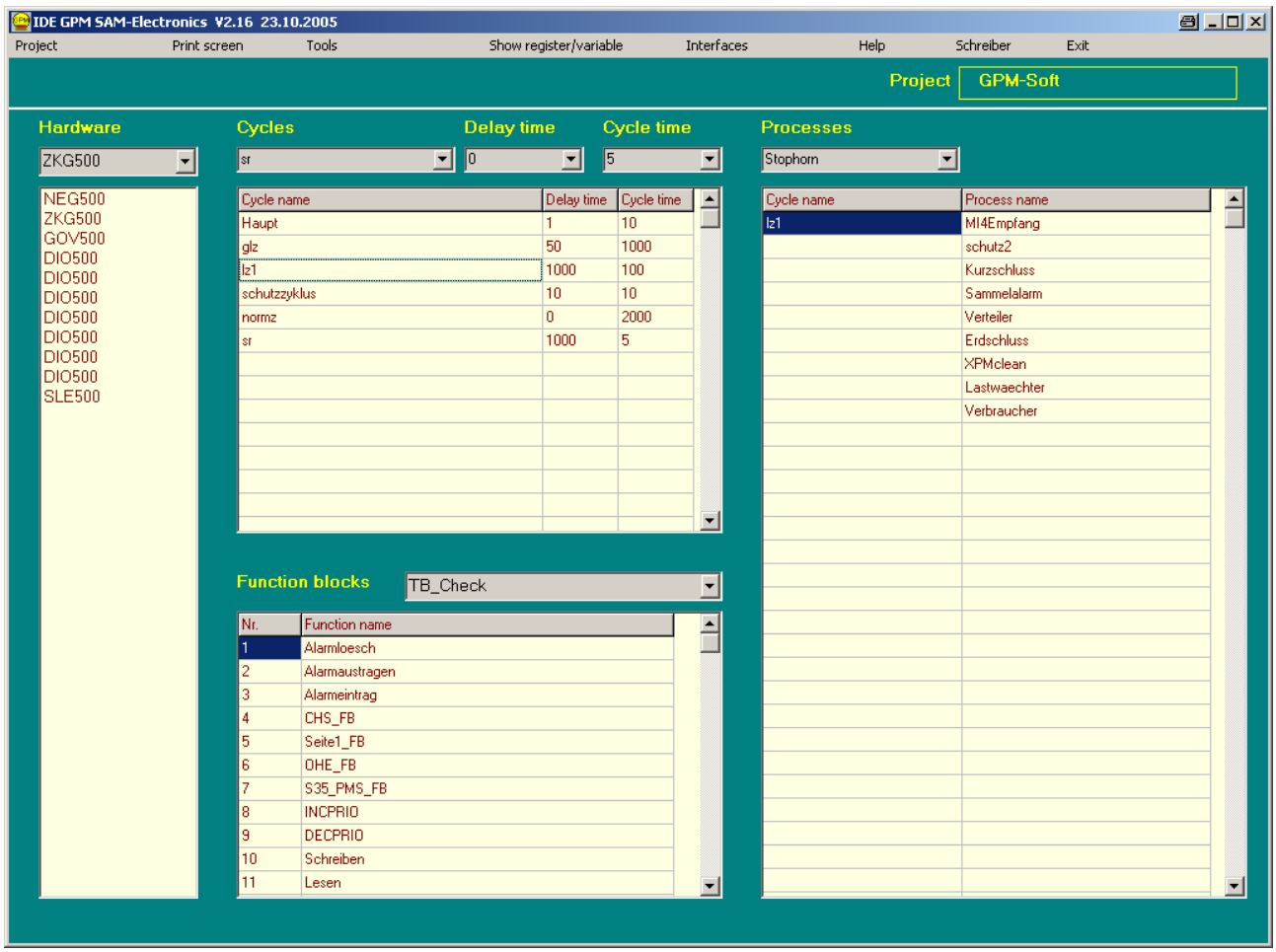


Diagram 14.2.3Main Menu

Four list elements are displayed:

1. Hardware descriptions
2. Description of cycles
3. Processes
4. Function Blocks

Processes and function blocks may be edited using an graphical editor (GPE). This editor may also provide an online access to the ZKG500s data:

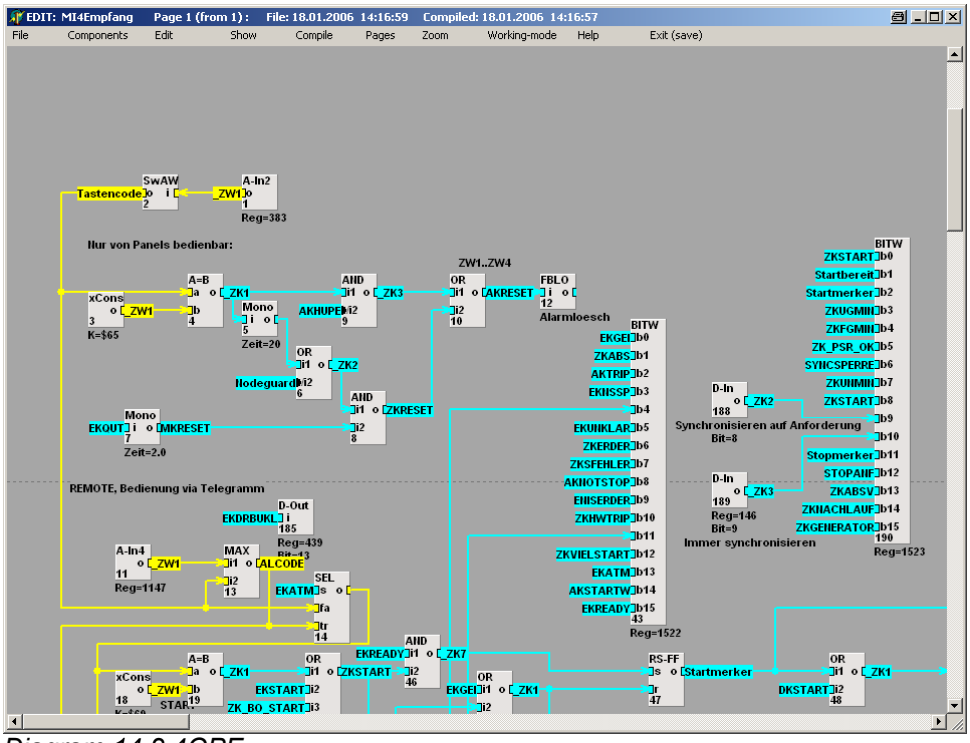


Diagram 14.2.4GPE

After changes the process must be compiled (Compile/Generate Code) and saved (Exit (save)!

The generated meta code must be linked by using “ZKG500” in the “Tools”-menu of the IDE. After linking the meta code the following window opens:

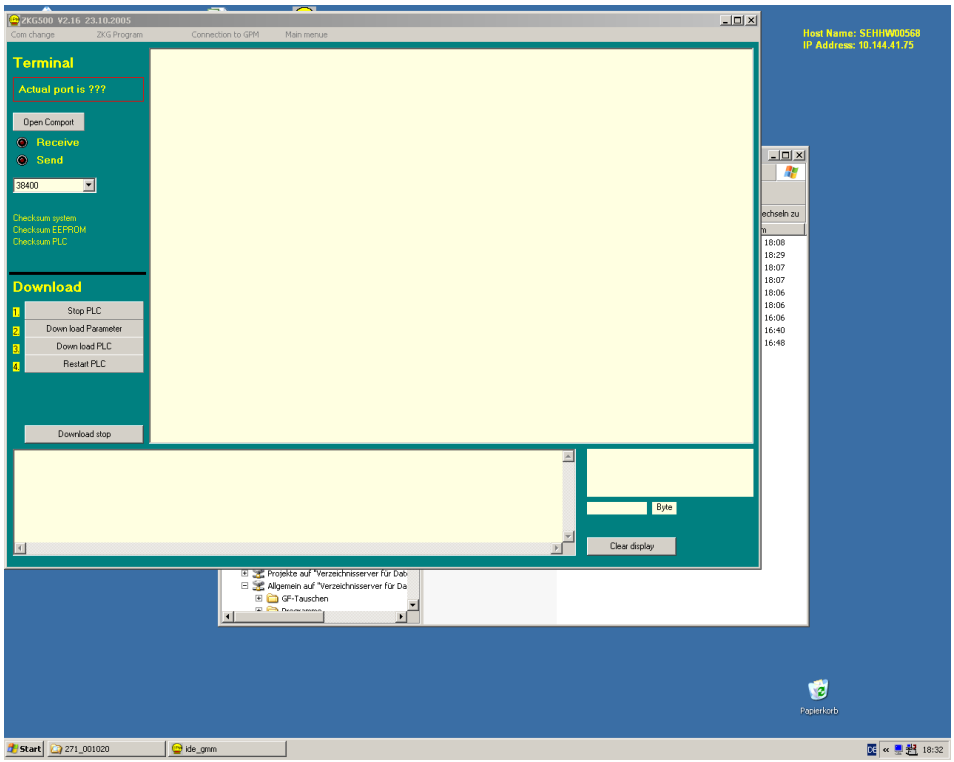


Diagram 14.2.5Terminal window

Here the assembler may be started to gain machine-readable code from the human-readable meta code: Menu “ZKG Program”/”Assemble...”! The assembling starts after clicking the paper stack symbol:

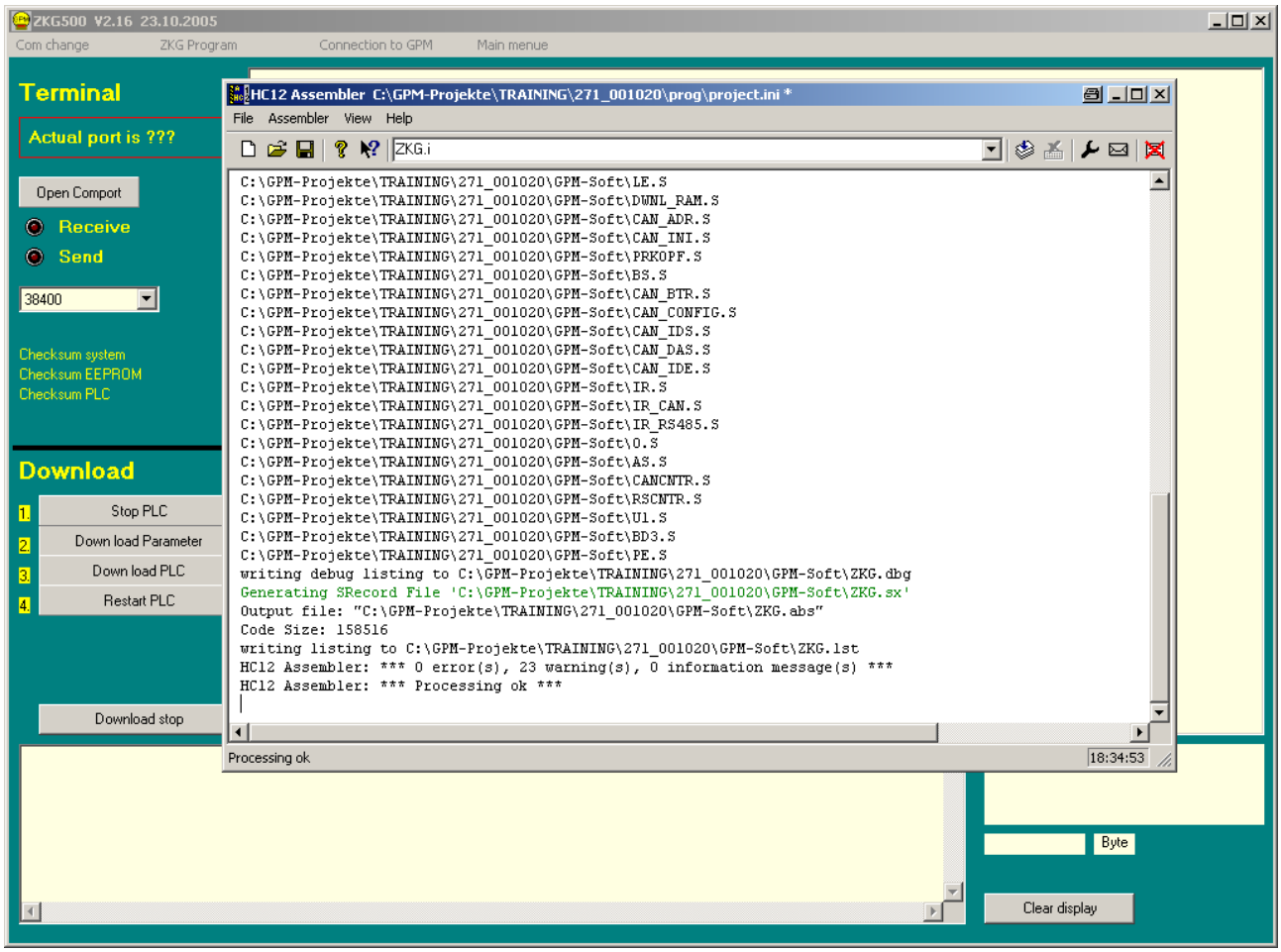


Diagram 14.2.6Assembler

The output in the file zkg.sx can be downloaded using the USB-Multilink tool:

UNIT 15 Program-Download



Diagram 15.1USB-Multilink from P&E

The adapter has to be plugged to the ZKG, red wire directed towards the LEDs on the surface. The multilink may be used with the debugger for download. The debugger may be started via menu “ZKG Program”, option “Download BDM multilink”

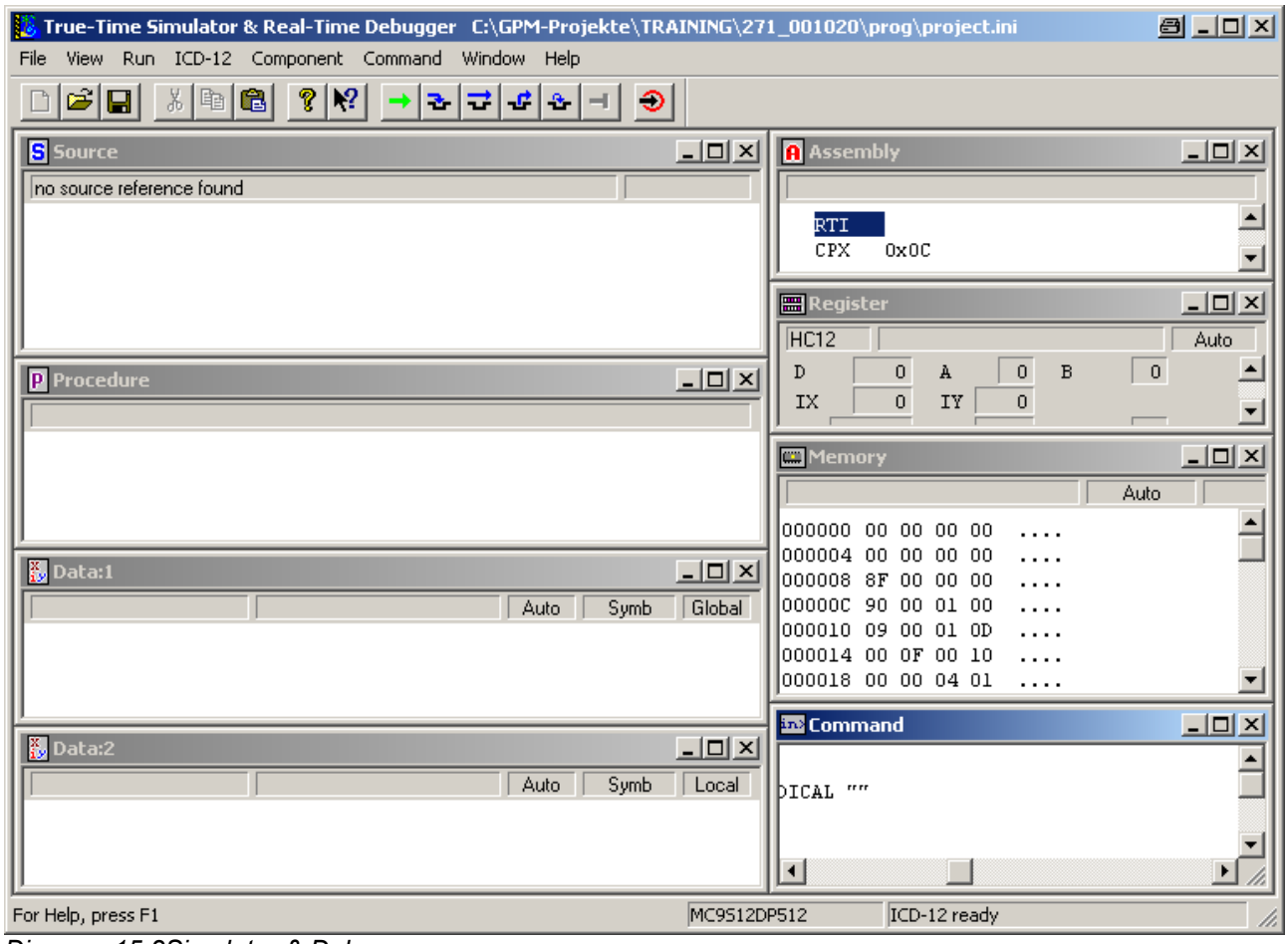


Diagram 15.2Simulator & Debugger

The debugger displays “ICD-12”-menu only with a proper connection. The “FLASH” option should be opened:

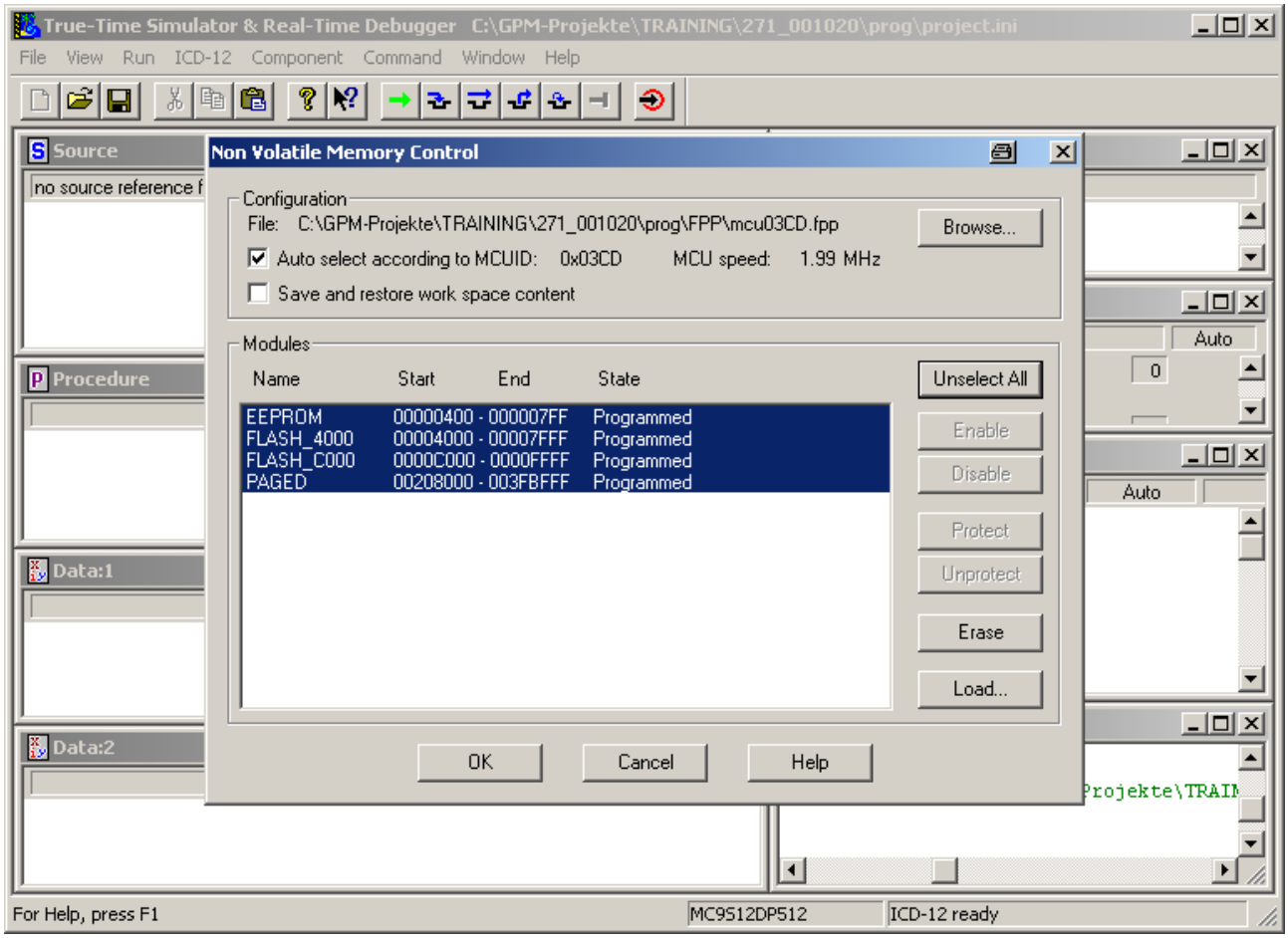


Diagram 15.3Memory control

The memory had to be erased using the “Erase” option. After that the new software may be stored using the “Load” option: (Make sure to select the ZKG.**sx** file in your project folder, you should not use files with other extensions!!)

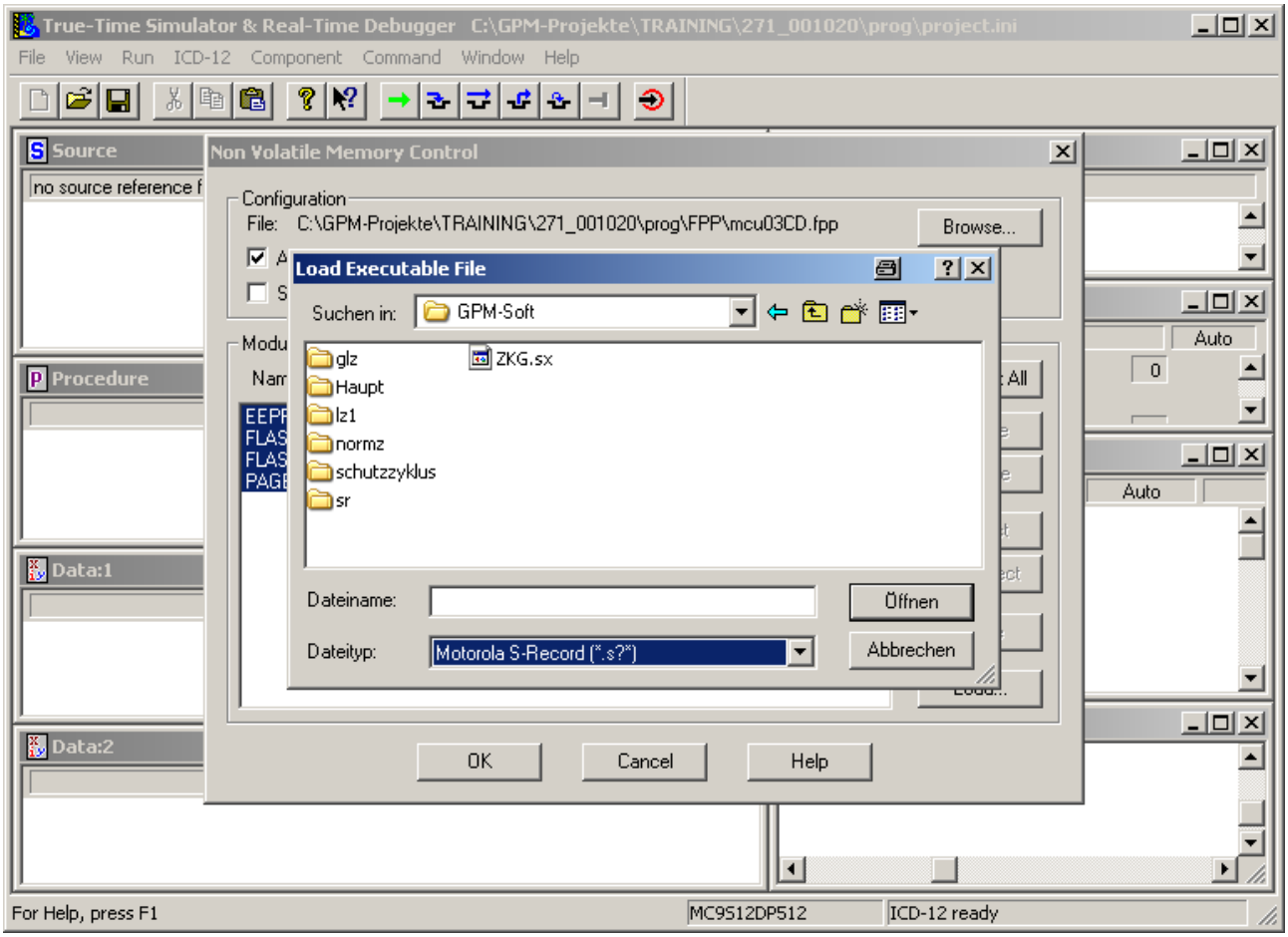


Diagram 15.4Load dialog

After double-clicking the ZKG.sx-file the download starts:

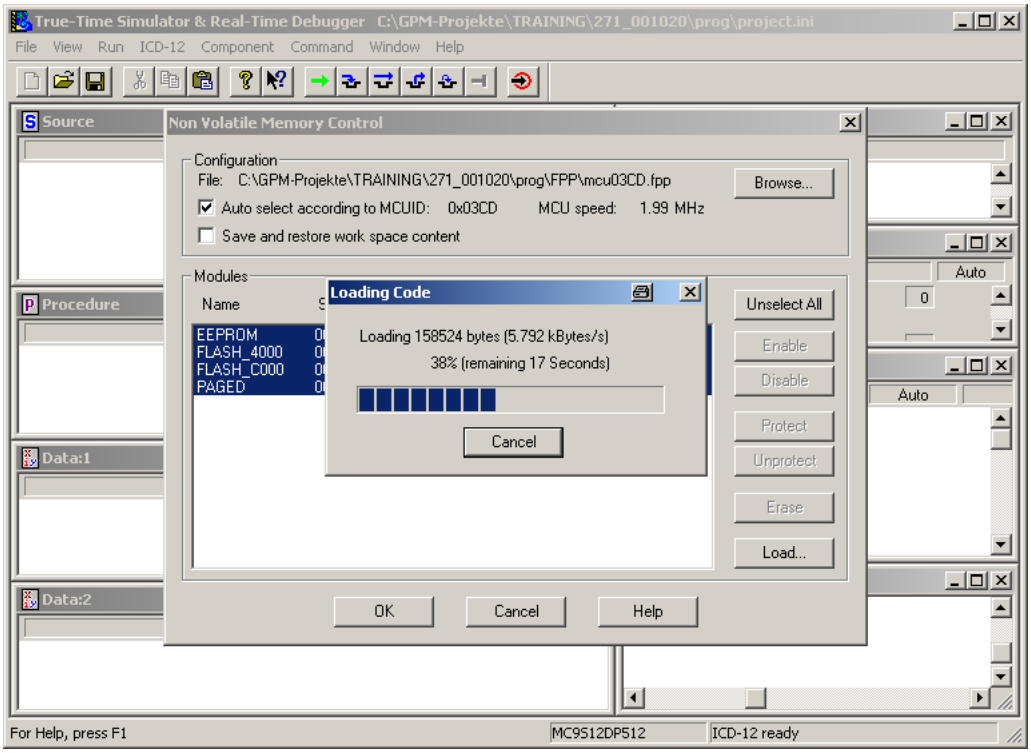


Diagram 15.5Loading ....

Make sure to click the “Reset Target” button (red circle and black arrow) after loading. Then click the green arrow symbol (“Start”). After that leave the debugger and disconnect the cable.

Now the serial interface (refer to 10.2.4) may be used to connect the Terminal screen to the ZKG500. Select the appropriate comport and click “Open Comport”. The “Open Comport” button changes to green, type the command “cp” to initialize the ZKG.

Finally, close the port again.

You may also first download parameters before typing “cp”. That makes sure, that the ZKG500 makes no false actions because of using standard parameter settings.

UNIT 16 Training 3:

UNIT 17 Special Applications

17.1 Tiebreaker

17.1.1 Synchronization

GPM500 is capable of synchronizing networks. The tiebreakers GPM own synchronization and load controllers like generators GPM[1]. The speed control pulses will not be generated by the tiebreakers GPM, but frequency set values are sent via bus to all GPM500 belonging to bus subnets neighboring the tiebreaker. Generators GPM500 become “slaves” of the tiebreakers GPM500, which is the “master” regarding the frequency. Both states are indicated on page 1 of the touch-panel for control. All GPM500 ´s are receiving the frequency settings at the same time because of the message broadcast typical for CAN.

Only one tiebreaker synchronization, shaft generator synchronization or tiebreaker unloading (subnet separation) is possible in one subnet because a special CAN telegram of high priority is used for this purpose, which will not be sent by more than one device at the same time.

17.1.2 Subnet separation / Unloading

It is good practice to reduce the load on tiebreakers before opening them to build separate subnets.

Unloading may be achieved using the same way of generator control as in case of tiebreaker synchronizing. Again the tiebreakers GPM500 will act as “master”, the generators GPM500 will act as “slave”.

Therefore it is required to assign new subnet numbers to the devices on both sides of the tiebreaker. The tiebreakers GPM500 stops to transport network numbers between both sides, so the respective devices are assigned to different subnets (before actually opening

1 It should be mentioned here, that generators and tiebreakers software is exactly the same, if some hardware requirements are met.

the tiebreaker!!).

Only one tiebreaker synchronization, shaft generator synchronization or tiebreaker unloading (subnet separation) is possible in one subnet because a special CAN telegram of high priority is used for this purpose, which may not be sent by more than one device at the same time. (refer 5.1.1).

Remark: Readers, who are familiar with GMM10, will experience, that subnet separation seems to be not interlocked if spare power is not sufficient. The “STOP” button (page 1) starts flashing, the disconnection is initiated, two subnets are build. But often the breaker will not be opened, because spare power calculation for one of the newbuildubnets may show, that disconnection is forbidden, when bustie transfer power is taken into account. At least one generator will be started and connected to gain enough spare power. **Then** the tiebreaker will open if its load is lower 10 % of its rated power. If that is not possible, a stopfailure alarm may be given to inform the operator, in special cases stop-failure may be defined as trip alarm to open the tiebreaker anyway.

Start-passing may also be used with tie-breakers: If a tiebreaker should be opened e.g. because of ground-overvoltage the tiebreaker's GPM starts with network-separation after 20 s. If necessary, additional generators will be connected by the GPM´s PMS and subsequently the tiebreaker will be unloaded and finally opened. If unloading is impossible, tiebreaker will be opened after delay given by Par. 90!

A special problem comes up, if the tiebreaker is part of a ring. In this case unloading of the breaker is technically impossible, the tiebreaker's GPM is not capable of addressing an UP- and a separate DOWN-subnet before opening. So it is normally impossible, to open tiebreakers inside a ring in AUTO mode. That limitation can be overruled by parameter (Par.189, Bit 11). If Bit 11 is set, the respective breaker will be opened on request without further checks, if only a ring structure is detected. Usually Bit 11 is only set for certain tiebreakers![1]

17.2 Shaft-Generator

17.2.1 Shaft Generator Synchronization

A synchronous shaft generators (SG) frequency is defined by the main engines speed and usually not be influenced by the respective GPM500. So the GPM500 of the SG becomes master and sets the frequency set-point for other generators of the subnet. Frequency controller should not be activated with shaft generators.

17.2.2 Shaft Generator Unloading

Shaft generators disconnection may be initiated also if the SG is running solo. The “STOP” button (page 1) starts flashing, other generators GPM are calculating the remaining spare power (which will be negative). So at least one start condition will be met, one generator set will be started and connected.
After that the SG will be unloaded by setting appropriate frequency set values for the generator sets and at least be disconnected. Refer to Diagram 7.6.2!

It is strongly recommended to disable the SG´s PMS because connection and disconnection of the SG should only be initiated by the operator. It must be taken into account, that DG sets will be started in case of insufficient spare power. DG and SG may

1 Normally it is strictly forbidden to open a medium-voltage tiebreaker as long as an parallel connection through low-voltage segments is maintained!

run parallel in that case, ***GPM500 provides no interlock!***

It is up to the designer to create an appropriate interlock, which creates either an stop signal (DIO500#1:DI 1) to the shaft generator or to a tiebreaker! The PMS function will automatically start sufficient DG sets to maintain power supply in that case!
PMS is disabled during SG operation by using the NoDGStart signal!

17.3 Emergency & Harbor-Generator

17.3.1 Introduction

GPM500 for Emergency Generators EG and combined Emergency & Harbor generators EHG must perform additional duties compared to normal GPM500:

- EG- and EHG-GPM500 must control one or two transfer lines to main switchboards
- EG- and EHG-GPM500 must stop the emergency diesel after mains-recovery
- The generator should be connected to the network on demand without having blackout to test the diesel.
- EHG-GPM500 must be able to react in different ways to abnormal conditions depending from their operation mode (Harbor/Emergency)

17.3.2 Hardware

17.3.2.1 Digital IO

A third DIO500 is needed to provide additional inputs for the EG- and EHG-GPM500. So a DIO500 for preferential trip must be added (and defined by setting Par.189, Bit 3) whether needed for that purpose or not!

DIO500#3:12 (DI 4): Emergency generator mode selected

DIO500#3:13 (DI 5): Synchronizing requested for interconnection breaker 2

DIO500#3:14 (DI 6): Synchronizing requested for interconnection breaker 1

DIO500#3:15 (DI 7): transfer line breaker 2 CLOSED (DOWN 3 used)

DIO500#3:16 (DI 8): transfer line breaker 1 CLOSED (DOWN 2 used)

DIO500#3:1, 2 (DO 3): Emergency generator mode selected

It should be kept in mind, that DI 7 and DI 8 also change the DOWN-parameter used. So the EHG is using another subnet number and is included in spare power calculation of the respective subnet.

17.3.2.2 Mains voltage

The input for mains voltage (TRV500: 5, 8) must be connected behind transfer line

breaker 2, if DI5 is set and behind interconnection breaker 1, if DI6 is set. It is very important to have the the correct voltage, when starting the synchronization. DI5 and DI6 should be deactivated, if one of the interconnection breakers is closed. In that case the input for mains voltage (TRV500: 5, 8) must be connected to the emergency busbar again!

17.3.2.3 GPM-Bus

No connection to other GPM is needed, if there is no loadsharing between the emergency/harbor generator and the main generators. Often automatic loading and unloading for EHG and other generators is demanded. In that case we need the bus connection to the main generators GPM to share information like “CB closed” and actual power.

17.3.3 Device Types

Three device types are covered by this document

Device **3**: Emergency Generator

Device **5**: Emergency & Harbor Generator

Device **6**: Emergency & Harbor Generator with second interconnection

(There is no need to provide Device x “Emergency Generator with second interconnection” because it can be implemented using device type 6 without enabling harbor made!)

17.3.4 Tripping

The special feature of device types 5 & 6 is that the breaker will not be tripped by most normal protection functions as long the generator is in Emergency Mode. Protection parameters must include the function code BBB (Bit 7) to trip in Emergency mode. Otherwise tripping is restricted to harbor mode!

17.3.5 Synchronization

All devices (3, 5, 6) are capable of synchronizing as well the EHG/EG with the emergency busbar as the emergency busbar with the main busbar (as long as the EHG/EG is connected!) After closing the EG/EHG breaker, the closing command output (SLE500: 29, 30) of the GPM must be redirected to the respective transfer-line breaker. The switchboard design must make sure, that the appropriate voltage is connected to TRV500: 5, 8 for synchronization. The new synchronization will be initialized by activating either DI5 or DI6 of the DIO500#3. *(Make sure not to redirect the OFF command (SLE500: 7, 8)!)*

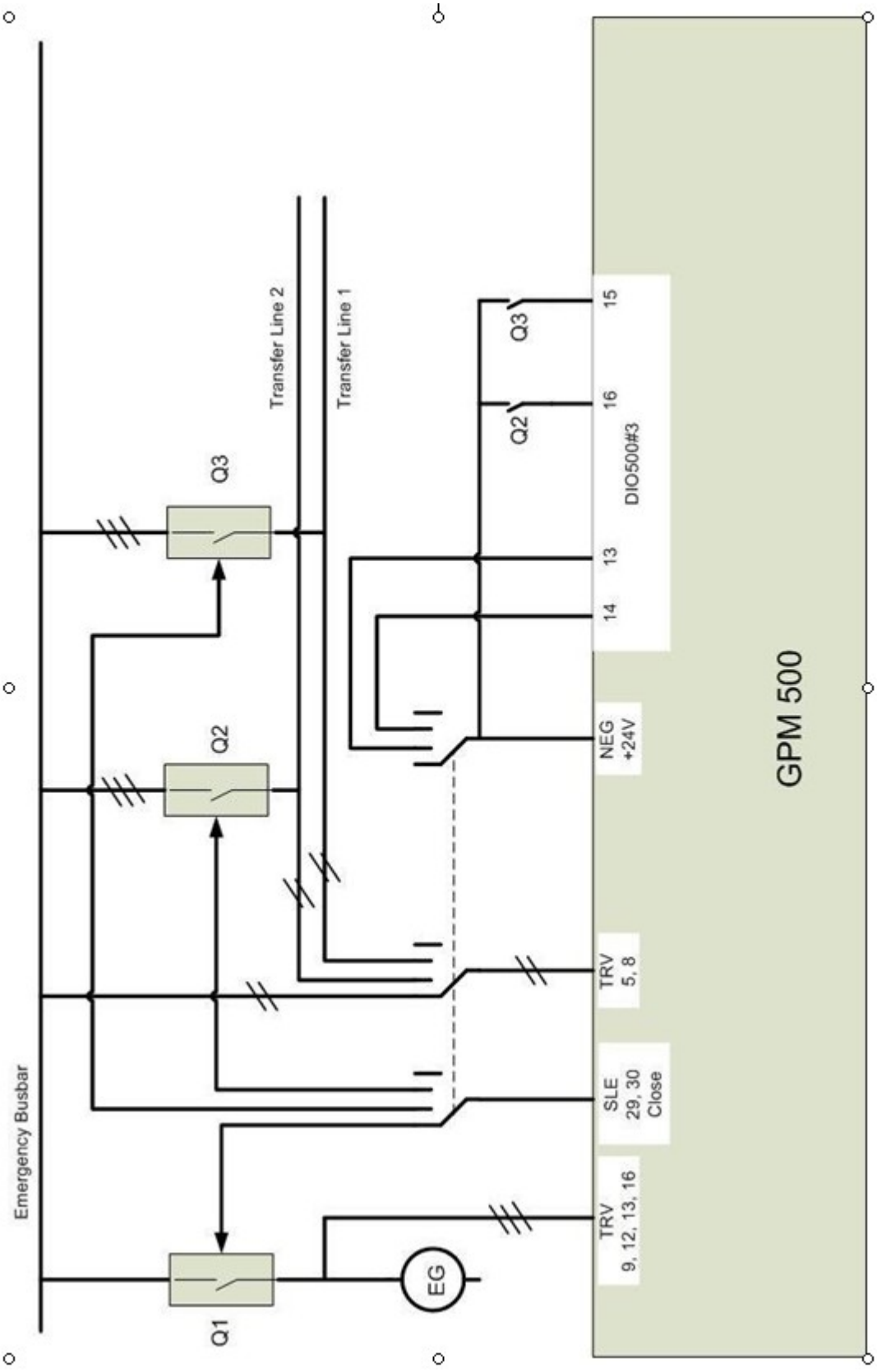


Diagram 1: Connections of the Emergency- and Harbor-Generator

As with main generators GPM two synchronization modes may be chosen:

- Synchronization starts automatically, because Gen Voltage is high enough (**Bit 9 of Par. 147 set!**)

- Synchronization requires a START command in addition (Touch-button, DIO500#1: 11 DI3) (**Bit 8 of Par. 147 set!**)

If DI5 or DI6 are activated, the appropriate transfer-line breaker symbol will start flashing to indicate, that the transfer-line breaker will be closed. After connection, the transfer-line breaker symbol will indicate the closed position. DI5 and DI 6 should be deactivated if one of the transfer-line breakers is closed.

Remark: The GPM is not capable of connecting the emergency switchboard and the main power supply,

17.3.6 Power Management

The PMS in Harbor mode is equal to standard PMS. In Emergency Mode, no load sharing is used because the generator is in solo operation in its subnet. If a transfer line is connected in EMERGENCY mode, the EG switches to TOPLOAD mode (trying to produce a power defined in Par. 175). This allows testing of the EG by running in parallel to the network.

If GPM-Bus is used, the parameters describing the network configuration must be set accordingly:

- Par. 162 (Low Byte) is the own busbar number of the emergency busbar **(e,g. DOWN 63)**
- Par. 162 (High Byte) indicates the main busbar, which is connected via transfer-line 1 **(DOWN2 61)**
- Par. 91 (Low Byte) is the main busbar, which is connected via transfer-line 2 (**DOWN3 62)**

So the EG/EHG GPM has three busbar numbers for the downstream side:

- If neither DI7 nor DI8 of DIO500#3 is activate, the EG/EHG GPM assumes running alone.
- If DI7 is activated, the EG/EHG assumes running in parallel to the generators connected to transfer-line 2
- If DI8 is activated, the EG/EHG assumes running in parallel to the generators connected to transfer-line 1

17.4 Shore-Connection

17.5 Consumers

UNIT 18 Diesel Protection Module DPM500

18.1 Start

For a Diesel start the following preconditions have to be met:

- Operating Mode “Remote”
- Signal “Ready to Start” from the engine
- No actual or unacknowledged alarms

If all criteria are met, the voltage supply for the start relay on the Start / Stop Module SST 500 is released by the Central Processing Unit ZKG 500.

The Diesel start is activated by:

- the operator
- using the external start button
- using the start soft key at the BAT 500
-

In Manual – and Automatic mode

- using the soft key at the Monitoring System (optional)

In Automatic mode

- the DPM 500 as Stand Alone device (e.g. for an emergency Diesel)
  - at Black Out (contact input)
- GPM 500
  - at Black Out
  - on power request (Load monitoring)
  - on start request from another aggregate in case of failure

18.2 Alarm Start

In case of Black Out, the DPM 500 provides an (optional) digital output to the diesel control to suppress monitored start criteria as pre lubrication pressure, and thus insure a Black Out start.
The start preconditions and the start sequence are monitored. The monitoring criteria are fitted to engines requirements by parameter setting.
A start order is indicated to the GPM 500 in order to cancel a possible idle running for cooling down.

18.3 Diesel Stop

18.3.1 Normal Stop

The Diesel stop is activated by:

- the operator
- using the external Stop button
- using the stop soft key at the BAT 500
- using the soft key at the Monitoring System (optional)

in all operating modes.

In Manual mode the stop is carried out immediate and the generator breaker is opened by the DPM 500. In Automatic mode the stop order is passed to the GPM

500. If load condition allows the stop, the GPM 500 discharges the generator, opens the generator breaker, keeps the engine idle running to cool down and than gives the stop order to the DPM 500 to stop the engine.

the GPM 500 in Automatic mode

- on sufficient spare power (Load monitoring)

18.3.2 Alarm Stop

The Diesel stop is activated by:

- the DPM 500 at following monitoring criteria:
- Overspeed Standard
- Lubricating oil pressure Standard
- Cooling water temperature Standard
- Cooling water pressure
- Lubricating oil temperature
- Fuel Leakage
- Exhaust gas temperature
- Bearing temperature
- CO_2
- Oil Mist concentration
- TC Overspeed

To adapt the monitoring criteria to the requirements, every one has two function bytes to describe the reaction following the particular event. The function bytes are parameters, where the reaction is defined by setting the corresponding bits. The contents of the function byte is listed up in the following table:

Code / Bit Pos.			***Description***	***Value (hex)***	***Value (dez)***
OP	**OP**	**0**	Alarm Active; setting this bit activates the monitoring for the criterion	01	1
STP	**STP**	**1**	Stop; engine will be stopped after time delay, set by parameter	02	2
SWG	**SPR**	**2**	Start; start command to a stand-by aggregate (via GPM 500)	04	4
ALU	**SUP**	**3**	Alarm suppression on engine standstill	08	8
		4		10	16
ER	**LQ**	**5**	Local Quit / Reset; Alarm has to be acknowledged / reset at the DPM 500	20	32
NOT	**EMG**	**6**	Additional energizing of the emergency stop valve in case of monitoring stop	40	64
STU	**STS**	**7**	Stop suppression, when engine runs as emergency diesel (ordered by digital input)	80	128

There are no separate input signals for alarm and prealarm, alarm and prealarm are using the same input signal with different time-delay.

An alarm-stop is carried out in all operating modes. For Overspeed the Alarm

and the Stop bit are internally set, the Stop suppression bit (7) is internally inhibited. For criteria with set stop suppression the alarm indication is still active.
The Diesel stop is monitored. The stop time is set by parameter. All monitoring inputs are line break monitored.

Every input is linked to three alarms (alarm, prealarm, linebreak alarm)!

18.3.3 Emergency Stop

For the “Emergency Stop” an external input is provided. Activation of the input leads directly hardwired to the outputs for Emergency Stop, Stop and Generator Breaker Off. The outputs are set as long as the input is set. The DPM 500 records the emergency stop order and sets the a.m. outputs also. If the input is not longer set, the DPM 500 keeps the outputs set for a time set by parameter. After expiry of this “Emergency Stop Time” the emergency stop has to be reset using the external Quit button.

18.4 Lubrication

The kind of prelubricating is selectable by parameter setting

- External / Manual

The prelubricating is externally controlled. If the corresponding input at the DPM 500 is set, on engine standstill the prelubricating pump is started and will be stopped, when the input is opened or the engine is started and above ignition speed.

- Interval Prelubricating

The pre lubricating is controlled by the DPM 500. The interval times for “Pump running” and “Pump stopped” are to be set by parameter. At Diesel Start the interval is interrupted and the pump is stopped. The input External / Manual overrides the interval cycle, i.e. the pump is started as described above. Is the input opened before the lubricating interval is over, the pump keeps on running until interval end or Diesel start. When the DPM 500 sets the output to start the pump, a monitoring time is activated. Within this time a feedback from the pump has to be given to the corresponding input, to indicate the pump running. If the time expires the alarm “Pre Lubricating Pump Failure” is given. In this case the DPM 500 indicates the engine as “Not Ready”.

- Start-Prelubrication

The pre lubricating is controlled by the DPM 500. After start order the pump will be started. The pre lubricating pressure is a start criterion. If the feedback is not set within a time set by parameter, the start sequence is cancelled and the alarm “Start Failure No Pre Lubricating” is given.
In case of Black Out the lubricating criteria are overridden to enable the Black Out start.

18.5 Fuel limitation

Parallel to the Diesel Start a digital output is set to limit the fuel injection at the engine. After reaching the ignition speed the signal remains for a time set by parameter.

18.6 Monitoring

18.6.1 Speed

The kind of speed measurement is selectable by parameter

- by contact from an external device for
- ignition speed
- overspeed
- speed pulses from Pick-Up (up to 3 kHz) for
- ignition speed
- operating speed
- overspeed (overspeed contact in addition recommended)
-

The speed signal serves for the monitoring of start sequence, running and stop sequence. Following alarms may occur:

- Start Failure - No Ignition Speed
- Start failure - No operating Speed
- Start Failure - No Prelubrication
- Tacho Failure (engine running, but no speed signal)
- Stop Failure (speed is above ignition speed after expiry of stop time)

UNIT 19 Introduction Project

UNIT 20 Training 4: The Project

UNIT 21 Conclusion / Summary / Questions