

Table of contents

16. POWER MANAGEMENT UNIT..... 2

 LOAD DEPENDENT START/STOP FUNCTION 3

 SELECTION OF START/STOP PRIORITY 8

 PLANT FREQUENCY CONTROL 10

 AUTOMATIC LOAD SHARE 11

 AUTOMATIC LOAD SHARE 12

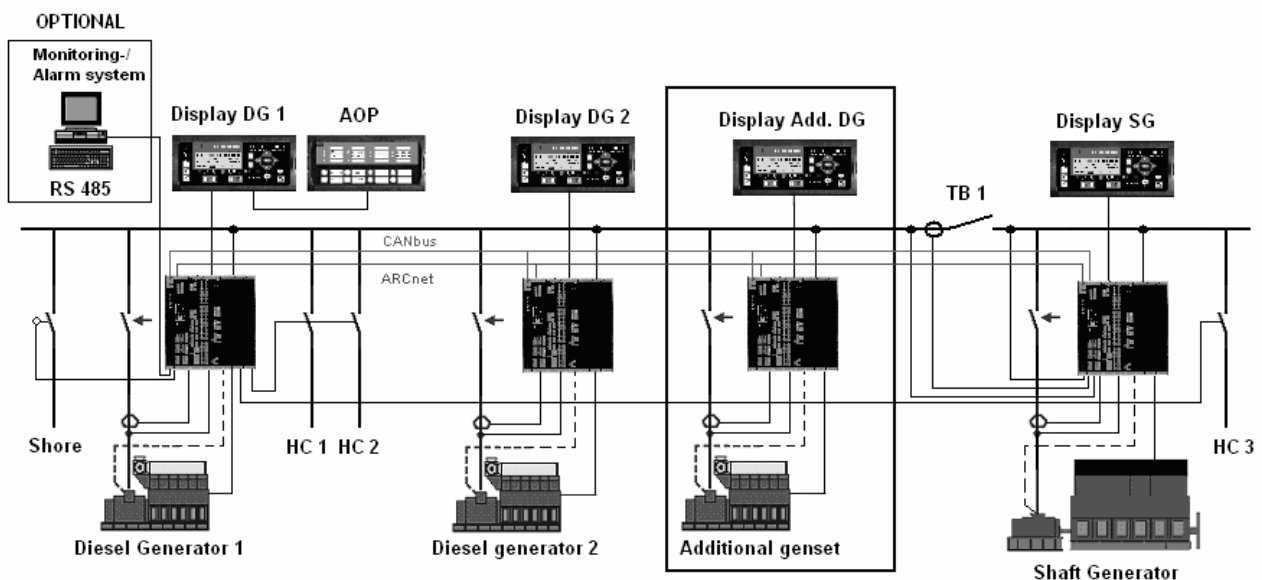
 BLACKOUT FUNCTION 15

 CONDITIONAL CONNECTION OF HEAVY CONSUMERS 17

 APPENDIX 16 22

16. Power Management unit

The Power Management System (PMS) unit is the *backbone* of the DELOMATIC system. The PMS unit controls *all* functions regarding superior or common control of the entire power plant by means of PMS commands.



Operating principle of the integrated PMS system

The PMS in the DELOMATIC system operates as an *integrated unit in the Main PMS DGU*.

The PMS interface in each DGU carries out distributed control of the generator sets according to the received PMS commands and PMS status feedback signals.

Only generator sets (DGUs) selected to be under PMS control are included in the automatic PMS functions.

Load dependent start/stop function

The load dependent start/stop function is active, when the AUTO or SECURED plant mode is selected and the shore connection is not closed. The start/stop function transmits PMS start and stop commands, which are based on a calculation of how many generator sets are needed in order to meet the actual power demand at the busbar. The PMS start/stop commands cause the individual generator sets to carry out start and stop respectively according to the programmed start/stop priority.

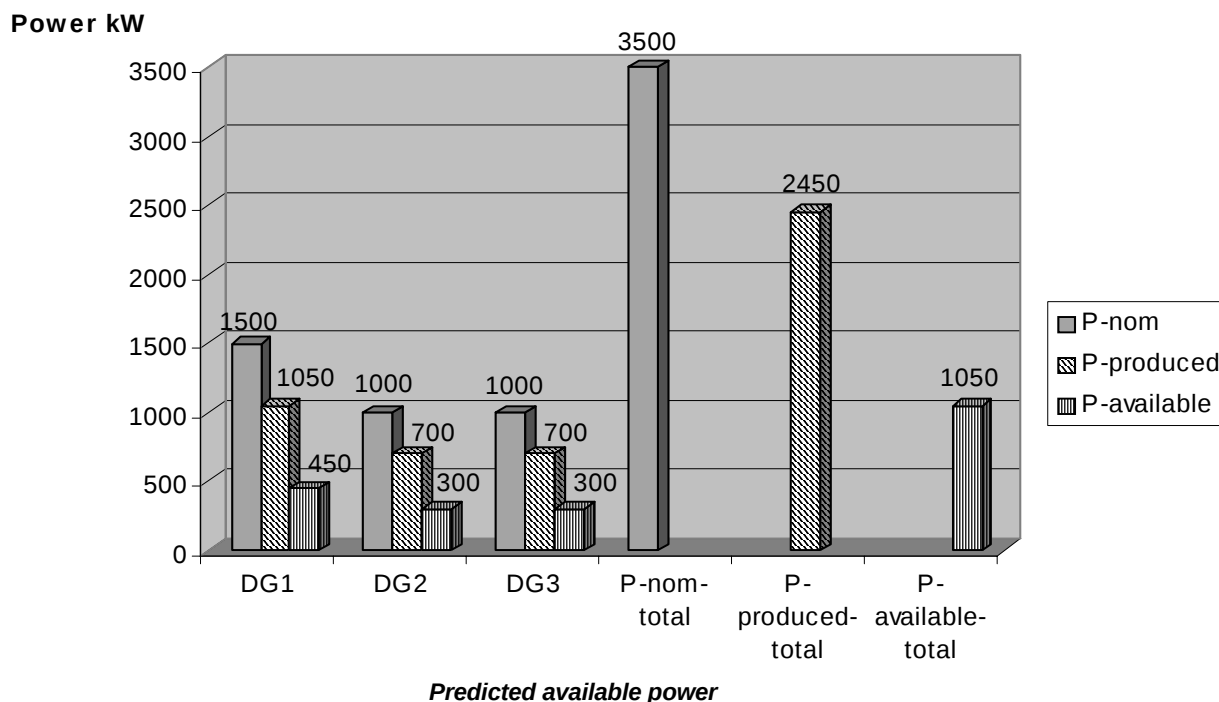
In SEMI-AUTO mode the load depending start/stop function will only allow a push-button initiated SEMI-AUTO disconnection of a generator breaker, if the generator set is surplus at the busbar (the predicted available power > the nominal power of the generator set). Calculation of the load depending PMS start/stop commands is based on a comparison of the programmed start and stop limits and a special DELOMATIC value called the *predicted available power*.

Predicted available power

In order to ensure sufficient available power at the busbar *at all times*, the DELOMATIC system uses a value called the *predicted available power*. Calculation of the predicted available power is based on a summation of the available power at each running generator set (see the illustration below). The result of the summation is the total *measured available power* at the busbar.

	DG P-nom	DG Load %	DG P-produced	DG P-Available
DG1	1500	70	1050	450
DG2	1000	70	700	300
DG3	1000	70	700	300
P-nom-total	3500			
P-produced-total			2450	
P-available-total				1050

Predicted Available Power



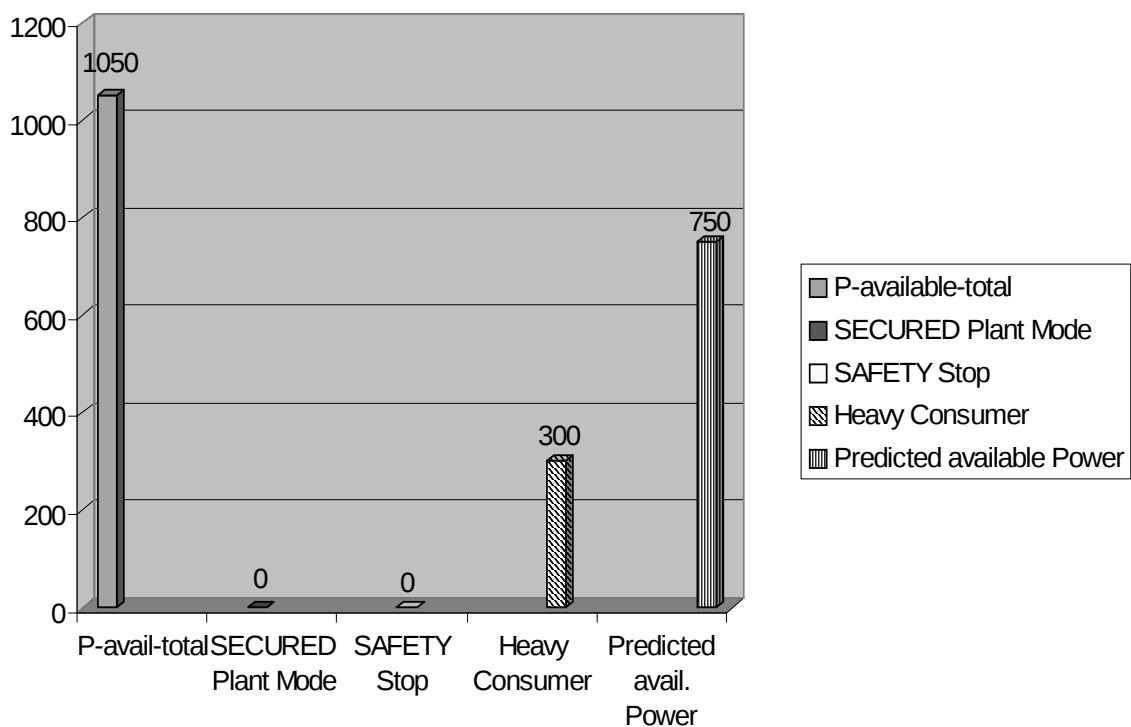
The predicted available power is subsequently calculated with consideration to the following events (all the below-mentioned events may be handled by the DELOMATIC system):

- The extra available power at the busbar during SECURED plant mode
- The nominal load of a running generator set which is about to be stopped due to a safety stop alarm sequence (expected stop)
- Conditional connection of heavy consumers

The common denominator for the above-mentioned events is the fact that they represent either a *predicted* significant loss of power production or a *predicted* significant increased power consumption at the busbar.

	P-avail-total	SECURED Plant Mode	SAFETY Stop	Heavy Consumer	Predicted avail. Power
P-available-total	1050				
SECURED Plant Mode		0			
SAFETY Stop			0		
Heavy Consumer				300	
Predicted available Power					750

Predicted available power



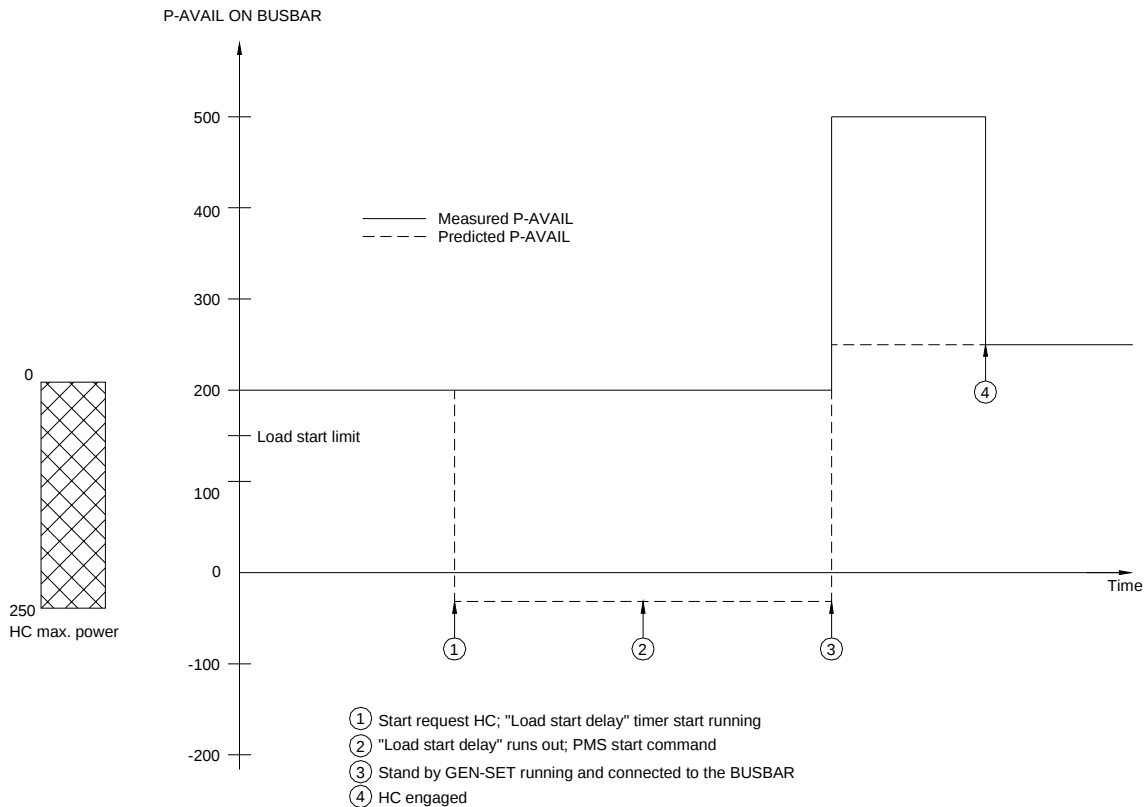
Predicted available power

The calculated *predicted available power* is compared with the programmed load depending start/stop limits in order to generate the PMS start/stop commands.

Programming of the load dependent start limit

Generation of the *load dependent PMS start command* is based on a comparison of the predicted available power at the busbar and the programmed start limit value.

Please refer to *Appendix A.16.1* where the operating principle for generation of the load depending start command is presented by means of a flow chart.



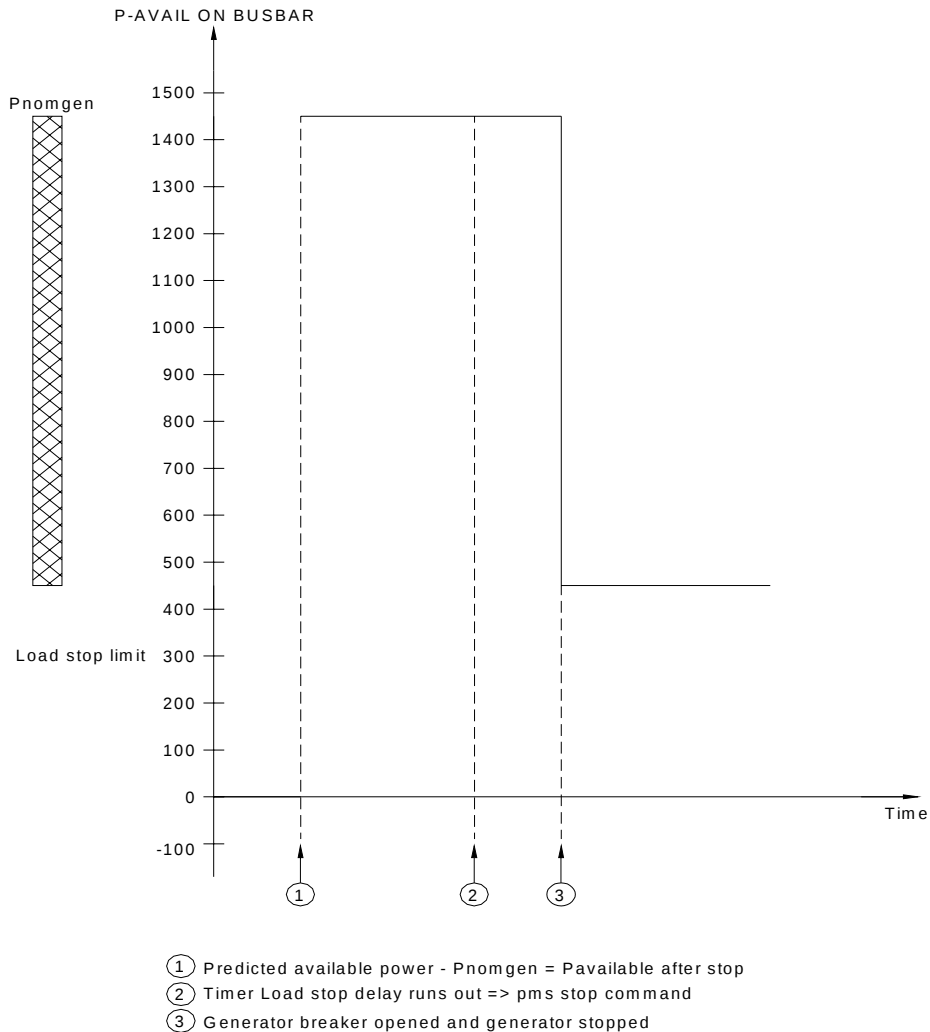
Load dependent start

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

The operator is able to adjust the following VTA structure **LDStart**, by which the transmission of the load depending PMS start command is controlled.

Programming the load dependent stop limit

The PMS stop command is generated by comparing the programmed stop limit value with the result of the following calculation: *The predicted available power deducted from the nominal load of the generator set designated with the highest stop priority.*



Load dependent stop

The programmable stop limit represents the desired remaining available power at the busbar, *after* the load dependent PMS stop of the generator set has been carried out.

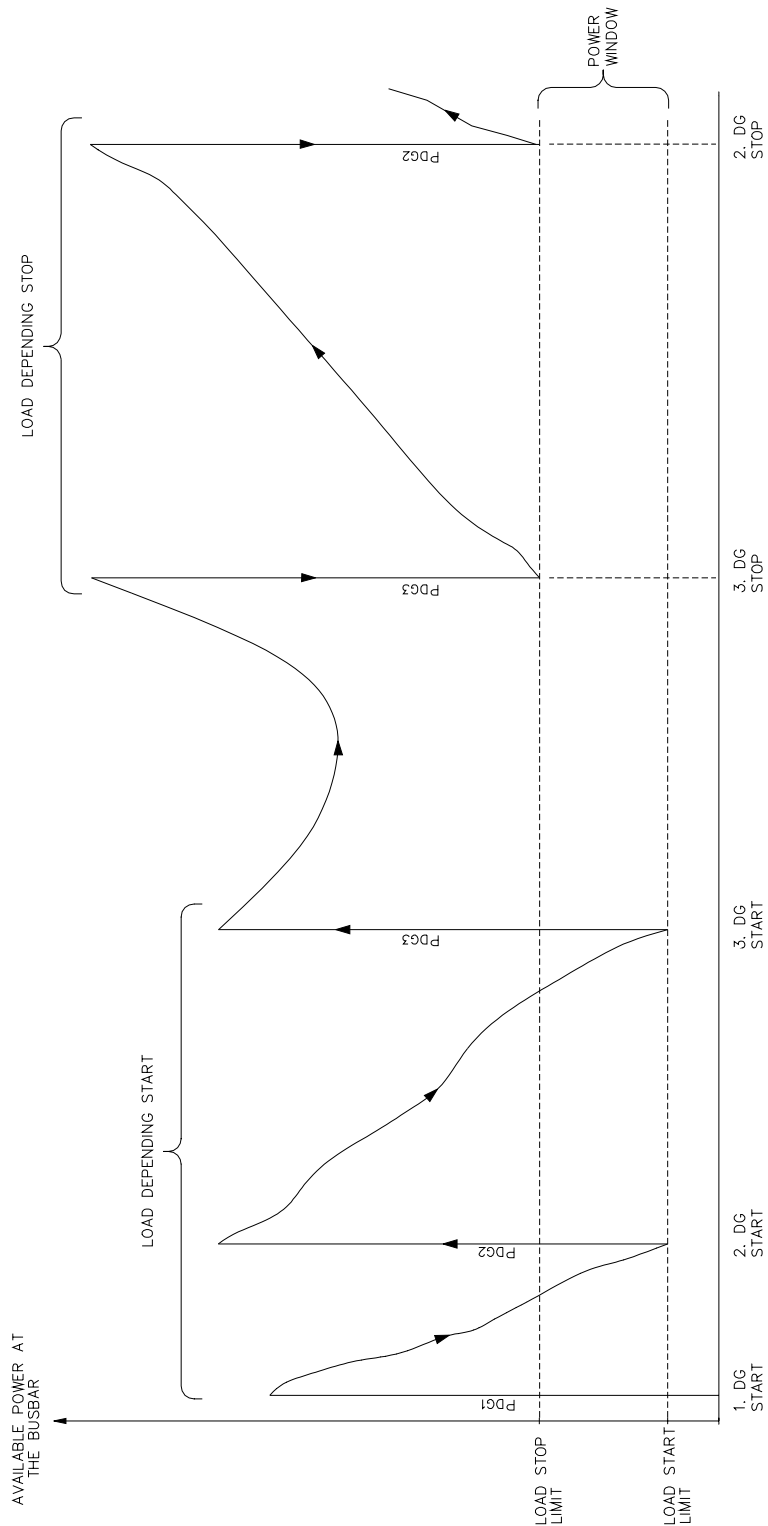
Please refer to *Appendix A.16.2.* where the operating principle for generation of the load depending stop command is presented by means of a flow chart.

The PMS command for load dependent stop is transmitted time delayed to avoid unnecessary stop of running generator sets due to brief load variations.

The operator is able to adjust the following VTA structure **LDStop**, by which the transmission of the load depending PMS stop command is controlled.

The power window

The difference between the programmed values "LOAD STOP LIMIT" and "LOAD START LIMIT" forms the power hysteresis between start and stop (the power window).



A load depending start/stop example stated with 3 generator sets

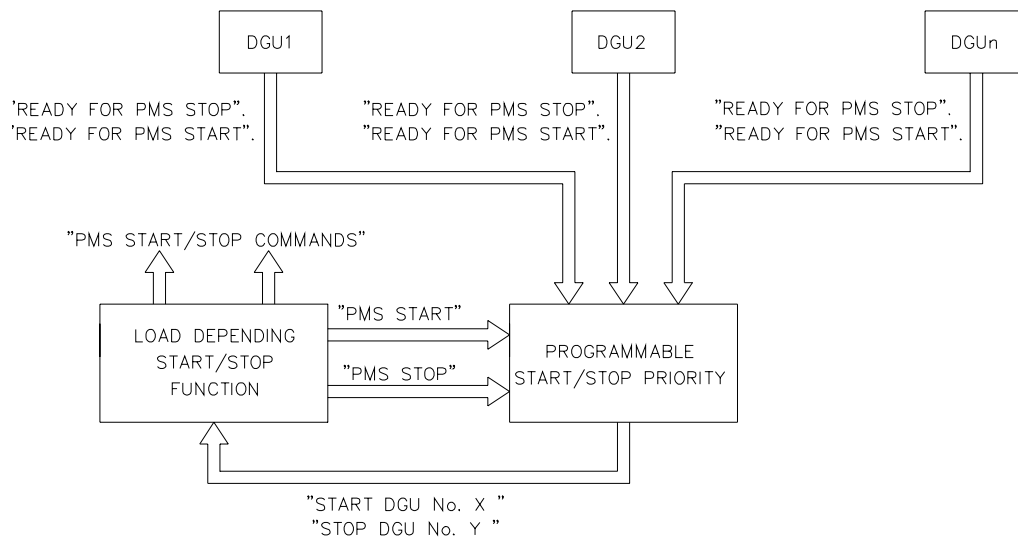
Transfer of the PMS start command

A PMS start command is automatically transmitted to the next stand-by generator set, if any of the below-mentioned alarm sequences become active at a running generator set:

- The **"SAFETY STOP"** alarm sequences
- The **"TRIP OF GB"** alarm sequences
- The **"SHUTDOWN"** alarm sequence

Selection of start/stop priority

Depending on the programmed priority sequence and the operational status of the generator sets, the start/stop priority function continuously designates each generator set with a *PMS start priority* and a *PMS stop priority* respectively. The load depending start/stop function uses this information when the PMS start/stop commands are to be transmitted.



Operating principle for determination of the start/stop priority



The start/stop priority function keeps track of which DGUs are "ready for PMS start", and which DGUs are "ready for PMS stop". Any running DGU, which during operation becomes not "ready for PMS stop", is not accepted as the next generator to be stopped.

Programming of the start/stop priority sequence

Programming and read-out of the start/stop priority sequence are carried out for all generator sets through the DU (Main PMS DGU).

(Please refer to the paragraph GENERAL MENU SYSTEM for more information on where to locate the priority sequence submenu for control of the start/stop priority function.)

The DELOMATIC system will not accept the start/stop priority sequence if:

- Two or more generator sets are programmed to the same start/stop priority number, or a generator set is programmed to have several start/stop priority numbers

The example below shows a start/stop priority sequence for a 4 generator set power plant, programmed to start priority 2-3-1-4.

START PRIORITY	
DGU no.	2 - 3 - 1 - 4
Start priority	1st 2nd 3rd 4th



The DELOMATIC system is able to control the start/stop priority for as many as 15 sets.

When the operator changes the priority sequence, the generator sets automatically rearrange according to the new start/stop priority



Any stand-by generator sets, which have been designated with a higher start priority than any running generator sets, will automatically substitute these.

Determination of the start/stop priority

The Main PMS DGU continuously designates each generator set with a PMS start/stop priority number according to the programmed priority sequence.

The priority sequence 2 - 3 - 1 - 4 designates

- DGU no. 2 with *start/stop* priority no. 1 (to be started first)
- DGU no. 3 with *start/stop* priority no. 2
- DGU no. 1 with *start/stop* priority no. 3
- DGU no. 4 with *start/stop* priority no. 4 (to be started last)

The DGU designated with *start* priority no. 1 is indicated by

- a *green* "1ST STARTBY" LED

A priority sequence 2 - 3 - 1 - 4 designates

- DGU no. 4 with *stop* priority no. 1 (to be stopped first)
- DGU no. 1 with *stop* priority no. 2
- DGU no. 3 with *stop* priority no. 3
- DGU no. 2 with *stop* priority no. 4

"1st PRIOR" push-button

The operator is able to designate the highest start priority to any generator set via the corresponding DU by pressing the

- **"1st PRIOR"** push-button

The example below shows how the start priority changes, if the operator presses the "1st PRIOR" push-button at the DU (DGU no. 4).

The start priority sequence *before* the "1st PRIOR" push-button is activated on the DU (DGU no 4):

2 - 3 - 1 - 4 meaning

- DGU no. 2 is designated with *start* priority no. 1 (to be started first)
- DGU no. 3 is designated with *start* priority no. 2
- DGU no. 1 is designated with *start* priority no. 3
- DGU no. 4 is designated with *start* priority no. 4 (to be started last)

The start priority sequence *after* the "1st PRIOR" push-button is activated on the DU (DGU no 4):

4 - 2 - 3 - 1 meaning

- DGU no. 4 is designated with *start* priority no. 1 (to be started first)
- DGU no. 2 is designated with *start* priority no. 2
- DGU no. 3 is designated with *start* priority no. 3
- DGU no. 1 is designated with *start* priority no. 4 (to be started last)

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

Plant frequency control

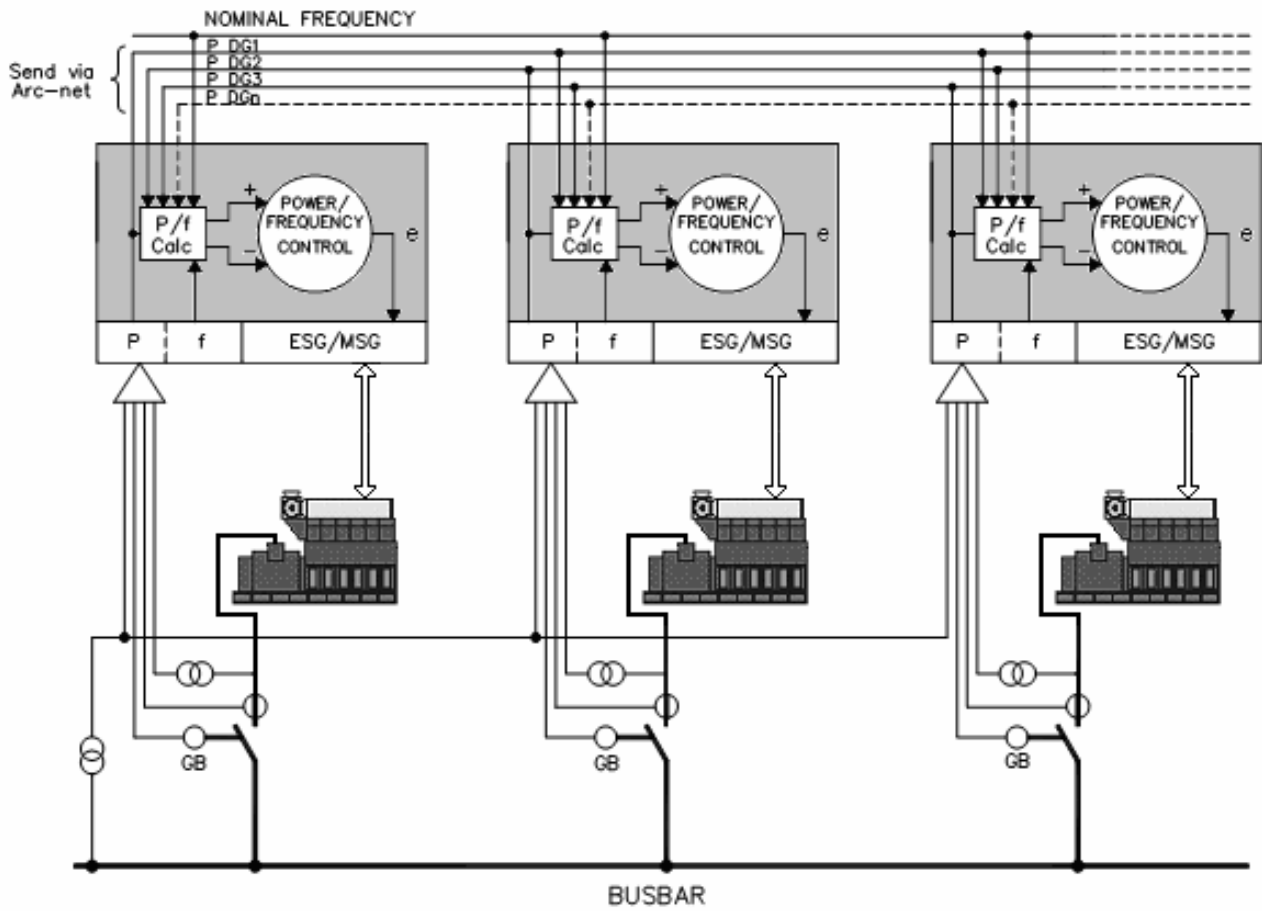
The DELOMATIC system handles the frequency control for the entire power plant in each DGU, which fulfils the following conditions:

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

The DGU ensures the plant frequency control and load control.

Implementation of frequency control

The target for the plant frequency control is always the nominal frequency of the power plant. Each DGU has an internal frequency reference characteristic. By means of the measured frequency, each DGU controls the frequency, until the frequency is inside the dead band for the frequency. This means that each DGU has influence on the common plant frequency.



Automatic load share

The DELOMATIC system is able to handle two types of automatic load share:

- Symmetrical load share
- Asymmetrical load share

Symmetrical load share

The DELOMATIC system handles symmetrical load sharing control in each DGU, which fulfils the following conditions:

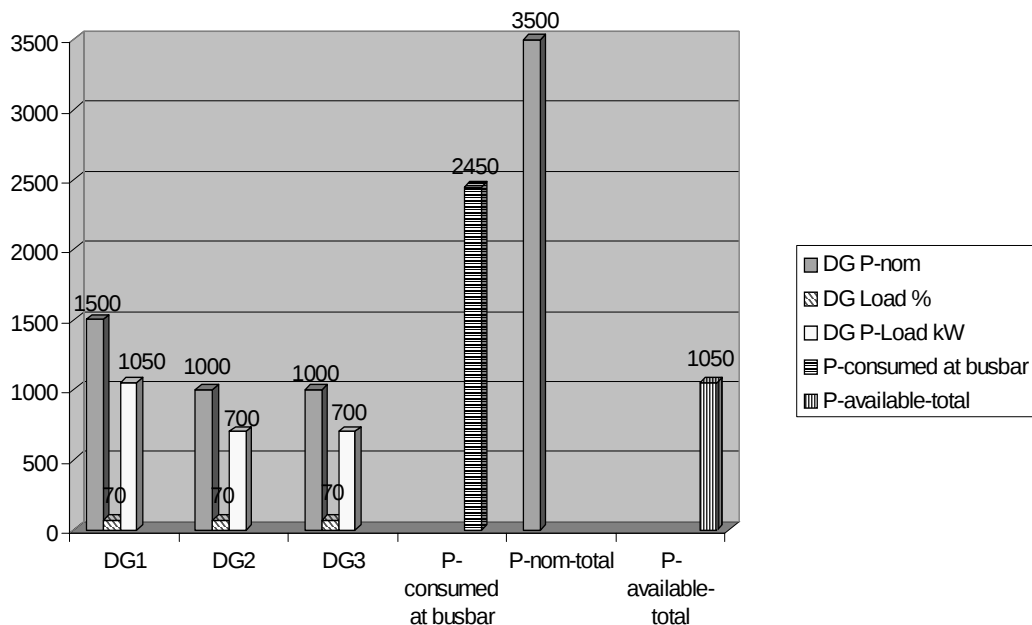
- PMS control is selected
- Does not carry out base load

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

During symmetrical load share, all running DGUs are producing the same percentage of their nominal power as the frequency controlling DGU. Each DGU calculates the sum of power and the number of DGUs, which fulfil the conditions for running symmetrical load sharing. The load reference for each DGU is the power consumed at the busbar divided with the sum of power.

	DG P-nom	DG Load %	DG P-Load kW	P-consumed at busbar	P-available-total
DG1	1500	70	1050		
DG2	1000	70	700		
DG3	1000	70	700		
P-consumed at busbar				2450	
P-nom-total	3500				
P-available-total					1050

Symmetrical load share



Symmetrical load share with 3 generator sets

For symmetrical load share:

- If the running generator sets have the *same nominal power*, they are loaded equally with real power (kW).
- If, however, the generators have *different nominal power*, they are loaded proportionally according to their size. This loads all generators with the same percentage of their nominal power.

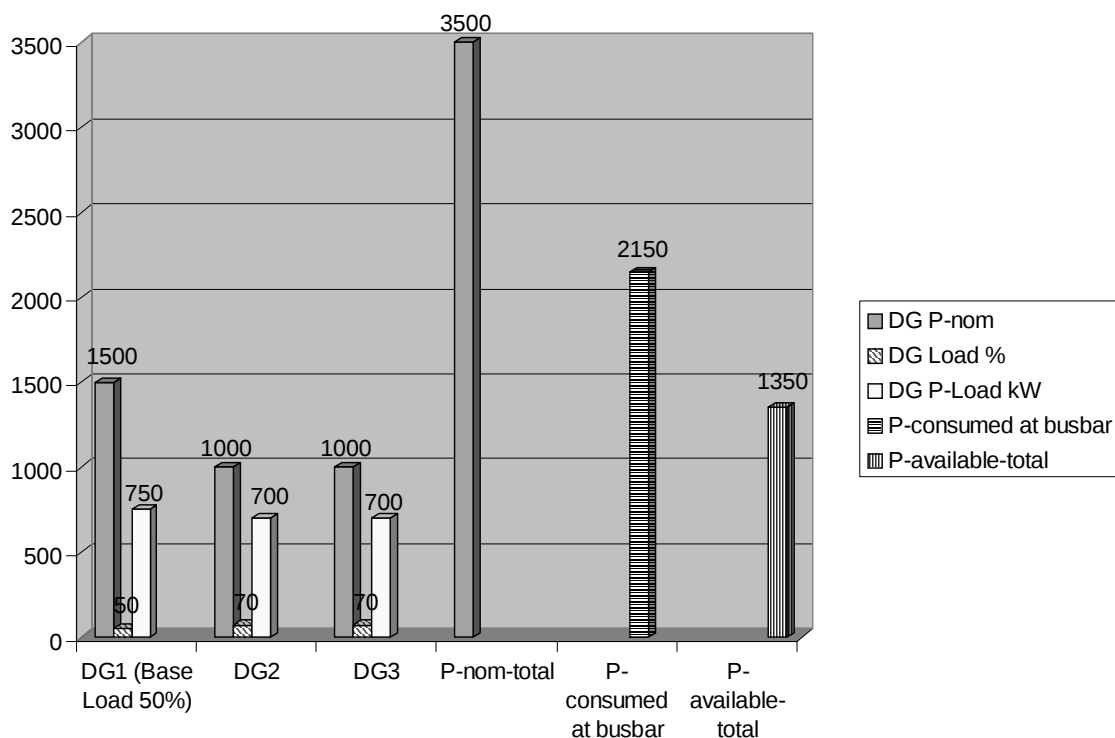
Asymmetrical load share

Asymmetrical load sharing is *only* carried out when selected by the operator. (Please refer to the paragraph THE GENERAL MENU SYSTEM for detailed information on how to activate asymmetrical load share).

When asymmetrical load share is selected, the DGU chosen to have the *highest start priority* will produce a programmable fixed base load.

	DG P-nom	DG Load %	DG P-Load kW	P-consumed at busbar	P-available-total	P-prod non base load gen.
DG1 (Base Load 50%)	1500	50	750			
DG2	1000	70	700			
DG3	1000	70	700			
P-nom-total	3500					
P-consumed at busbar				2150		
P-available-total					1350	
P-prod. non base load gen.						1400

Asymmetrical load share



Asymmetrical load share carried out with the base load

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

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

- **“DG P-BASE LOAD”**

Active asymmetrical load share is indicated at the DU (DGU which carries out base load) by

- a *green* **“BASE LOAD”** LED

Automatic cancellation of the asymmetrical load share function

The asymmetrical load share is automatically cancelled by the Main PMS DGU, if

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

The alarm message is displayed and indicated at the DU (Main PMS DGU), when cancellation is performed:

- Alarm **“ASYM.LD.SH.CANC”**
- A *yellow* **“BASE LOAD”** LED

Blackout function

The blackout function is active, whenever one of the following plant modes is selected:

- SEMI-AUTO mode
- AUTO mode
- SECURED mode

The blackout function consists of two separate functions:

- A common detection of "*dead busbar*" status
- The blackout start sequence

An individual detection of "*dead busbar*" status is made by all DGUs in the system.

The blackout start sequence is initiated once the Main PMS DGU receives the internal "*dead busbar*" status from all DGUs in the DELOMATIC system.

Please refer to *Appendix A.16.3* where the operating principle for generation of the blackout start is presented by means of a flow chart.

Dead busbar detection

The individual "*dead busbar*" internal signal is transmitted, when the following conditions have been continuously registered by a DGU during the programmable delay:

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

*A short circuit alarm at any of the DGUs will block the entire blackout start sequence.

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

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

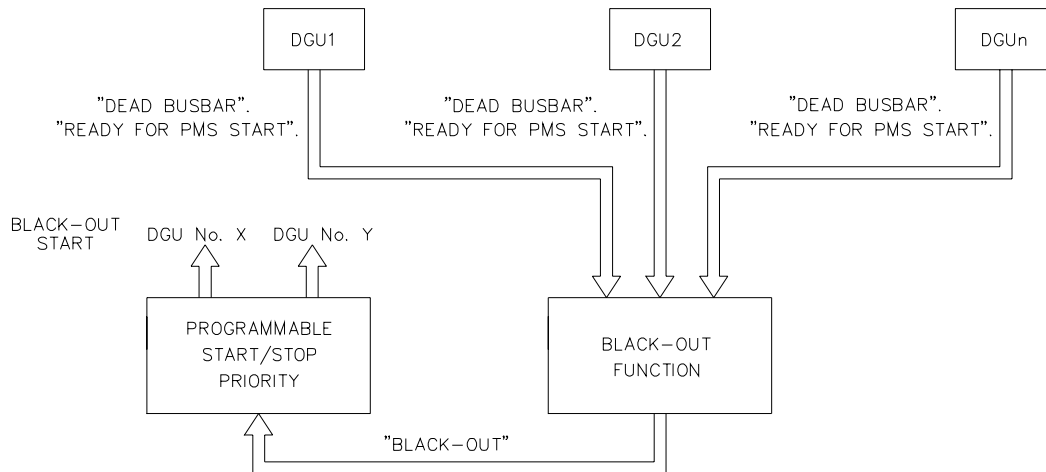
A synchronisation alarm is automatically acknowledged (reset) in case of an active "*dead busbar*" status in the DGU. This allows the generator set in question to attempt to connect to the busbar.

The blackout start sequence

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



Activation of the blackout start sequence is only possible, if at least one of the DGUs is selected to be in PMS control and "ready for PMS start".



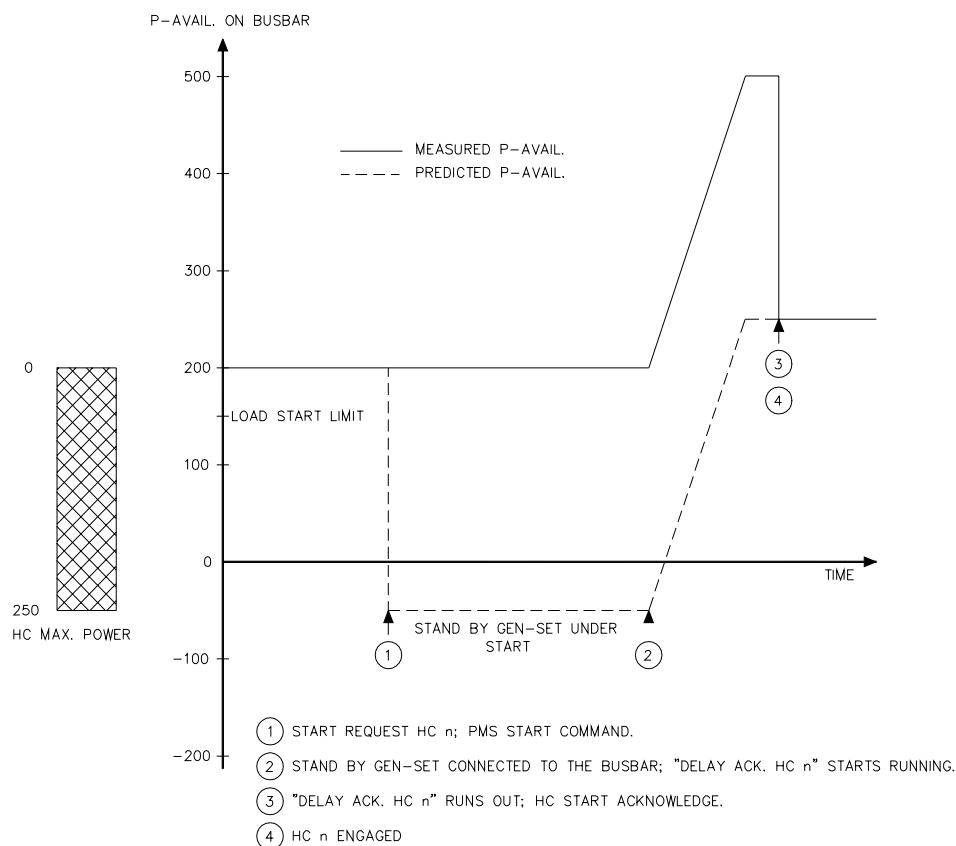
Operating principle of the blackout function

The blackout start sequence carries out the following step-by-step sequence:

- a) A PMS start command (activates the automatic start sequence in the DGUs) is transmitted to the DGUs with the highest and second highest start priority, which at the same time are "ready for PMS start".
- b) The DGU which first obtains normal running feedback and normal generator voltage/frequency will close the breaker immediately (after receiving an acknowledge signal from the Main PMS DGU).
 - b₁) If this does not result in the closing of the generator breaker, the other blackout started generator set will (after approx. 2 sec. delay) be requested to close this breaker without synchronisation.
- c) The second blackout started DGU initiates synchronisation of the generator breaker approx. 2 sec. after satisfactory voltage and frequency have been detected at the busbar.
- d) If any of the two chosen generator sets fail during the start sequence, the PMS start command is transferred to the next stand-by generator set, as long as the blackout situation is present.
- e) When one generator set is successfully connected to the busbar, the blackout function is considered to be completed, and the DELOMATIC system switches back to "normal" operation again.

Conditional connection of heavy consumers

When requested by a heavy consumer, the function for conditional connection of heavy consumers reserves the programmed max. power at the busbar and blocks for engagement of the heavy consumer, until sufficient predicted available power is present at the busbar.



P-reservation at the busbar before engagement of a HC (here 250 kW)

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

It may be necessary to delay the acknowledge signal in order to allow the recently started generator set to take load and thus actually increase the available power at the busbar before engagement of the HC. The acknowledge delay can be adjusted on the VTA structure **DelayAckHC(n)**.

The length of the acknowledge signal can be adjusted on the VTA structure **AckTimeHC(n)**.

The operator is able to change the maximum expected power consumption separately for each heavy consumer on the VTA structure **CFAnaHC(n)**.

The programmed maximum power is reserved at the busbar during the programmed delay time.



Please refer to technical manual part 1, paragraph 4 for a detailed description of the VTA structure.

The heavy consumers (HC) are connected according to their priority. HC1 is designated with the highest priority, e.g.: HC1 is handled before HC3, if they request start at the same time. If there are any preferential HCs, they must be connected to the hardware interface for HC1 in order to ensure 1st priority handling.

The DELOMATIC system carries out the following step-by-step sequence, when a HC requests start acknowledgement:

- a) The programmed "Heavy Consumer n set" value is reserved at the busbar.
- b) A PMS start command is transmitted to the next stand-by generator set, if the predicted available power is below the programmed "**LD. start**" limit.
 - b₁) If the predicted available power at the busbar is below 0 kW, the timer *HC* "**DelayAckHC**"*n* is blocked, until the stand-by generator set is connected and sufficient predicted available power can be measured at the busbar.
 - b₂) The timer *HC* "**DelayAckHC**"*n* starts running at this point, if the predicted available power at the busbar is above 0 kW.
- c) When sufficient predicted available power is present at the busbar, the timer *HC* "**DelayAckHC**"*n* starts running.
- d) The start acknowledge signal is transmitted to the HC in question, when the timer *HC* "**DelayAckHC**"*n* runs out and sufficient available power is still measured at the busbar.

Selection of heavy consumer power feedback type

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

- A HC with variations in load (**variable load** as a thruster) should always be assigned with an analogue power feedback.
- A HC with **constant load** can be assigned with binary power feedback, and the signal should be parallel to the circuit breaker for the load, meaning when the breaker is closed and the load is actually on the busbar, the power feedback signal should be high (CC). In this way ON/OFF control like e.g. heating elements and compressors can be handled.
- If, however, the load of the HC is a **constant load** and present whenever the HC is connected, the power feedback input should be selected as binary, and the input can be mounted with a short circuit bridge (always high, CC).

The DELOMATIC system is able to handle two types of power feedback:

- Binary feedback
- Analogue feedback

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

Changing the power feedback type is simply done by setting the jumpers (for designation as binary or analogue input channels) at the IOM 4-1 module. (Please refer to the paragraph SERVICE GUIDE for details).

The power feedback type may be selected as:

- Binary feedback (CC)
- Voltage feedback (0...10V DC, 2...10V DC is software controlled)
- Current feedback (0...20mA, 4...20mA is software controlled)

Cable supervision is automatically activated at all power feedback signals, which are selected as analogue inputs and set up for a 20% offset.



In order to avoid false cable supervision alarms, unused power feedback input channels should be jumped into the binary position.

Start of heavy consumers with binary power feedback

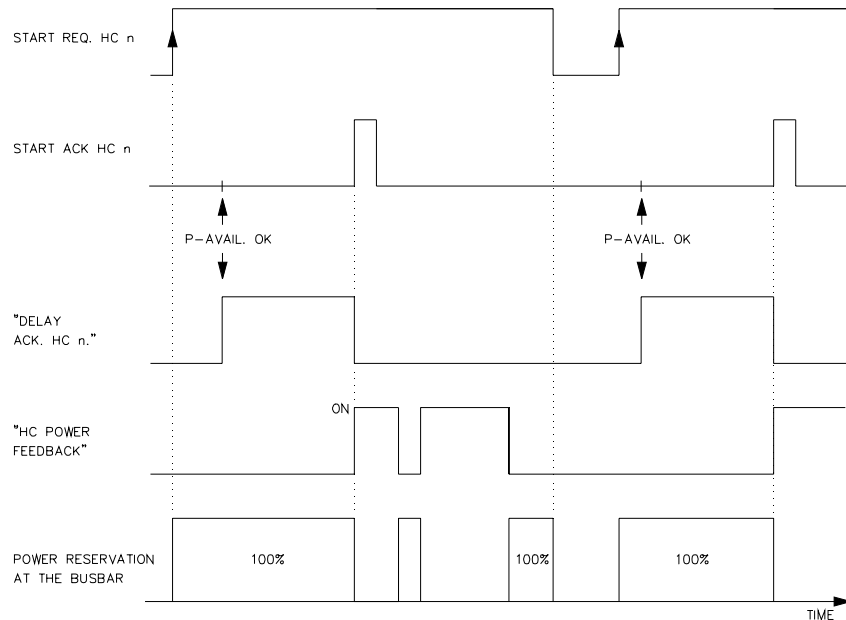
The conditional connection of heavy consumers with binary power feedback is controlled via the following hardware interface.

SIGNAL NAME	SIGNAL TYPE	LOCATION
• START REQ. HC n	Binary input	Main PMS DGU (IOM 4.1)
• HC no. n POWER FEEDBACK	Binary input	Main PMS DGU (IOM 4.1)
• START ACK. HC n	Relay output	Main PMS DGU (IOM 4.1)

Activating start request binary input makes start of a specific heavy consumer (HC n) with binary power feedback.

The DELOMATIC system transmits a start acknowledge signal when sufficient predicted available power is present at the busbar and the timer HC “**Ack delay**”*n* runs out.

The start acknowledge signal has a programmable ON duration, which the operator is able to adjust on the timer “**Ack length**”. Once the acknowledge pulse is transmitted, the HC is considered to be turned ON.



The engagement sequence for HCs with binary feedback

The power reservation by means of the power feedback input is enabled, as long as the start request signal is active.

An OFF status (indicates that the HC is not operating) at the power feedback signal results in a 100% power reservation at the busbar.

An ON status (indicates that the HC is operating) at the power feedback signal results in a 0% power reservation at the busbar.

Start of heavy consumers with analogue power feedback

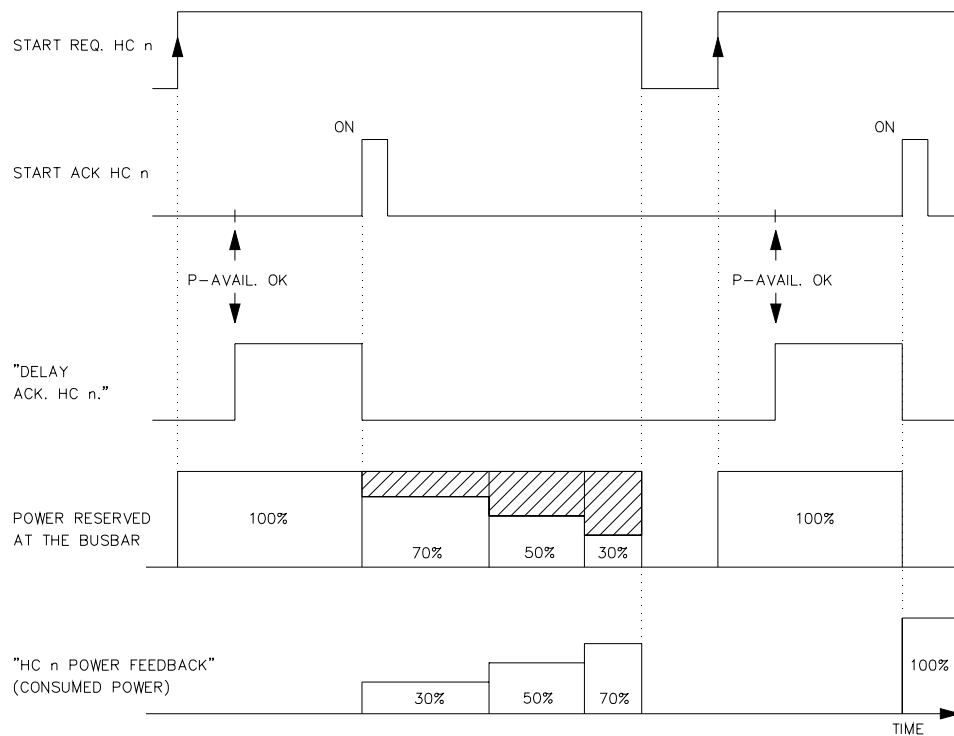
The conditional connection of heavy consumers with analogue power feedback operates via the following hardware interface.

SIGNAL NAME	SIGNAL TYPE	LOCATION
• START REQ. HC n	Binary input	Main PMS DGU (IOM 4.1)
• HC no. n POWER FEEDBACK	Analogue input	Main PMS DGU (IOM 4.1)
• START ACK. HC n	Relay output	Main PMS DGU (IOM 4.1)

Start of a specific heavy consumer with variable load (HC n) is made by activating the corresponding start request input.

The start request signal must remain activated, as long as the HC is to be in operation. Power reservation ends after the start request signal has disappeared.

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



The engagement sequence for HCs with analogue feedback

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

Adjusting the scale of the analogue power feedback signals

The scale of the HC's power feedback signals is defined as:

- 4...20mA correspond to 0...Max. scale

The operator is able to designate an arbitrary value as the max. scale of the analogue power feedback signal from the heavy consumers on the VTA structure **MaxScaleHC(n)**.



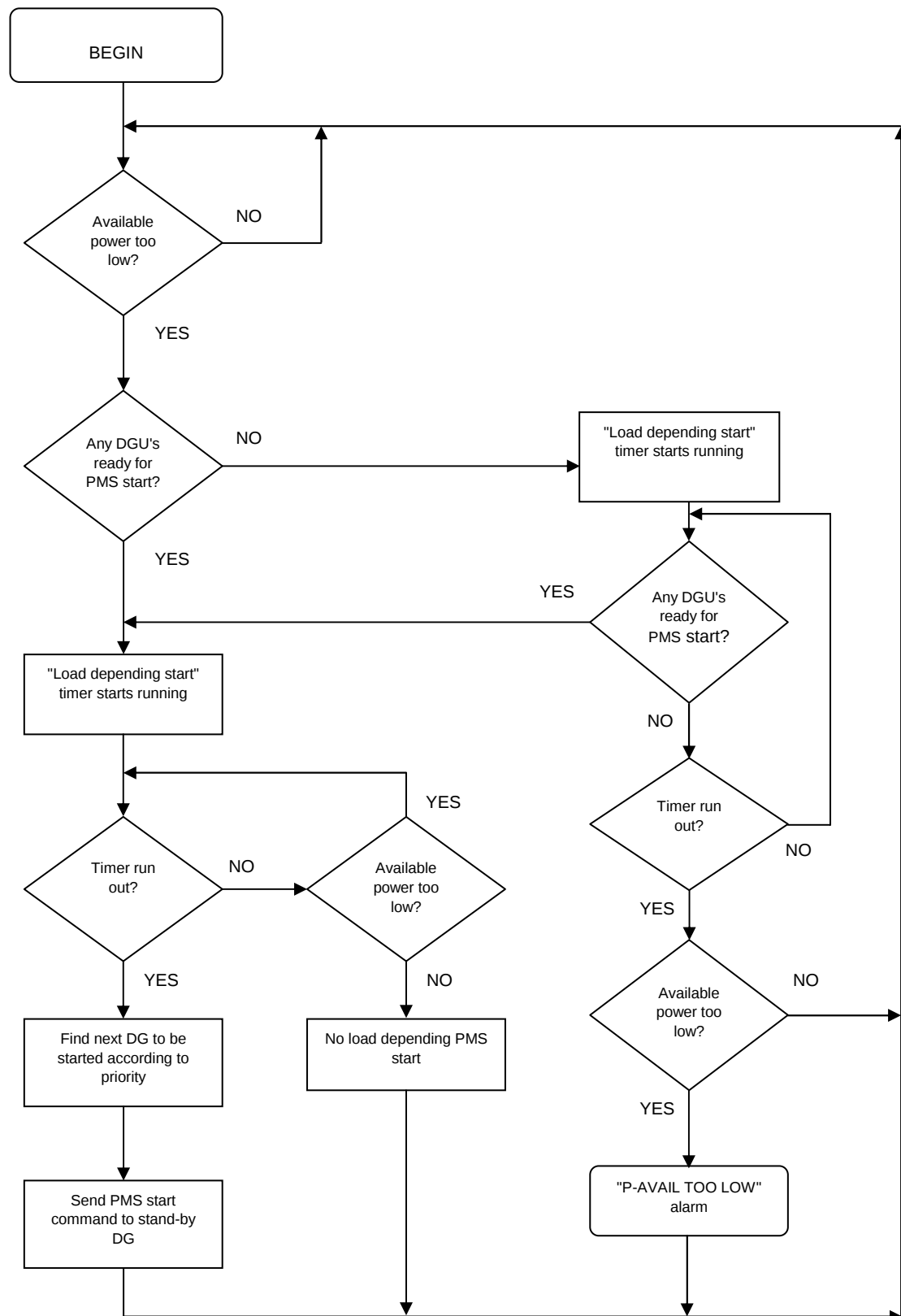
Cable supervision is active at all analogue HC power feedback inputs.

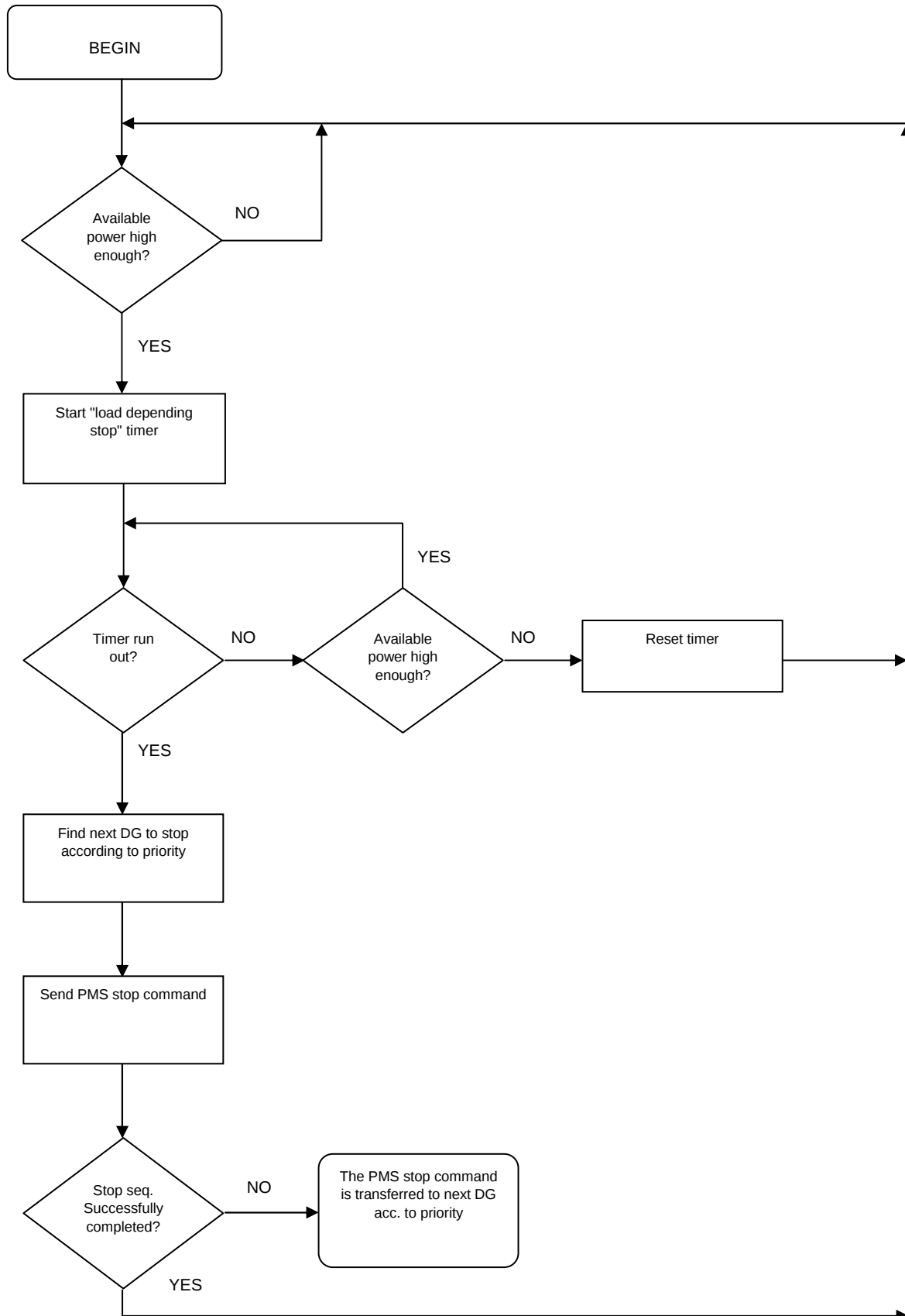


Please refer to technical manual part 1, paragraph 4 for a detailed description of the VTA structure.

Appendix 16

Load depending PMS start command flow chart



Load depending PMS stop command flow chart

Blackout start sequence flow chart