KONGSBERG

<table>
<tr><td colspan="6">Functional Design Specification
Power Management System
KM-Drill 8</td></tr>
<tr><td colspan="2">Project:</td><td colspan="4">12345678</td></tr>
<tr><td colspan="2">Product</td><td colspan="4">Integrated Control & Monitoring System</td></tr>
<tr><td colspan="2">Synopsis:</td><td colspan="4">This document describes the scope and functions of the Kongsberg Maritime Vessel Control system K-Chief as delivered to the specified vessel. Functions within other systems are not described in this document. This document when “as built” will serve also operator documentation together with KM standard K-Chief Operator Manual.</td></tr>
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1 About this document

1.1 Document history

Revision	*Description of Change*
A	Adjusted for Training Purposes

1.2 References

No	*Doc No*	*Description*
1	EA-01-5405-3	Engine Automatic System Doosan
2		MAN SaCoSone
3		MAN Load Sharing System

1.3 Definitions / Abbreviations

AFT	Afterwards
AUX	Auxiliary
ALC	Aqua master Logic Controller
AVR	Automatic Voltage Regulation
CB	Circuit Breaker

CCR	Central Control Room
DCS	Drilling Control System
DG	Diesel Generator
DGPS	Differential Global Positioning System
DPC-1	Dynamic Positioning Cabinet, redundant with network interface
DPC-3	Dynamic Positioning Cabinet, redundant with network interface
ECR	Engine Control Room
E/R	Engine Room
ESM	Engine Safety Module
FS	Field Station
FW	Fresh Water
FWG	Fresh Water Generator
FWD	Forward
DO	Diesel Oil
DG	Diesel Generator
HT	High Temperature
HPU	Hydraulic Power Unit
HV	High voltage (11 kV systems)
IAS	Integrated Automation System
LCP	Local Control Panel (Doosan)
LO	Lubrication Oil
LT	Low Temperature
LV	Low Voltage (440V / 220V, 60Hz systems)
MACH	Machinery
MGE	Main Generator Engine
SWBD(P,C,S)	Switchboard Board, Port, Centre and Stbd
OS	Operator Station (generally)
PMS	Power Management System
PS	Process Station, Process Control Cabinet
RCS	Remote Control System
RCU	Remote Control Unit
K-Pos	Kongsberg Dynamic Positioning
cJoy	Independent Joystick System
SHI	Samsung Heavy Industries Limited

K-Thrust OS	Operator Station Thruster Control
K-Thrust-400	Operator Station intended for manual thruster control
K-Chief	KM Vessel Control (equal to IAS in SHI documents)
K-Chief OS	Operator Station for KM Vessel Control system
SW	Sea Water
T/R	Thruster Room
VDU	Video Display Unit
VFD	Variable Frequency Drive
VMS	Vessel Management System

2 power management system

2.1 Introduction to the PMS system

This section details the philosophy underlying the design of the power management system for the Drill-ship. Proper operation of the power management system is essential to assure the safe, reliable, and economical operation. Consequently, the design premise for the power management system should be thoroughly understood by all engineering and operations personnel.

A reliable supply of electrical power is essential in any modern industrial process facility. The drill-ship is not immune to this concern. Because of the nature of the dynamically positioned drill-ship, Variable Speed Drives will be employed for the ship’s propulsion system. Variable speed AC drives will also be employed for the drilling systems. A dependable power source is critical for the successful operation of both systems.

For these reasons, the power management system on the drill-ship must be understandable, reliable, and effective. The power management system must keep operations personnel informed about the condition of the electrical power system, and should act promptly and effectively to prevent or correct situations which might result in an electrical blackout. To prevent blackouts, it is important to understand how they may occur.

1.1.1. Causes of Blackouts

Electrical blackouts result when electrical demand (load) exceeds the ability of the electrical system to meet the demand for electric energy. In an installation like the drill-ship, where all electrical power is generated on site (as opposed to depending upon an electrical utility for energy), the operators can control (within limits) both the electrical supply and the demand. As long as the system has been designed with sufficient electrical supply capacity (i.e., enough generating capacity to meet anticipated demands), avoiding blackouts becomes a matter of assuring that electrical demands are not allowed to exceed the capacity of the on-line generators.

Most offshore drilling rig blackouts occur when engine/generator sets unexpectedly shut down without warning. This type of blackout is a function of electrical power supply. Examples of this type of shutdown are; fuel system failure (clogging fuel lines, fuel pump failure, and the like), mechanical failure (loss of oil pressure, over speed and the like), control system failure (false indication of low lube oil pressure and the like), or human error. This type of shutdown is much more difficult to avoid than the type caused by excessive demand, but may be effectively handled if the power management system operates rapidly and effectively to reduce electrical demand to within the capacity of the remaining generators.

Other blackouts occur because fixed and variable load increases unchecked until the capacity of the on-line engine/generators is exceeded. This type of blackout is a function of electrical demand. As demand increases, the engine/generator sets must supply more power, until they reach and/or exceed their capacity. Then an engine/generator exceeds its real power capacity (kilowatts or kW), or its electrical capacity (Amperes or kVA), the engine overheats or the generator goes over current. As soon as the first engine shuts down due to over temperature or over current (and the resulting circuit breaker trips), a cascade of shutdowns ripples through any other running engine/generator sets, as they too exceed their thermal or current capacity. This class of blackout can be readily avoided by monitoring total energy demand in comparison to available supply and giving alarms or reducing load as required avoiding a blackout.

1.1.2. **Avoiding blackouts**

The traditional method of avoiding electrical blackouts in non-process industries has been to automatically shed non-essential electrical loads as demand approached capacity. Under this system entire loads or groups of loads are abruptly taken off the power system by simply tripping their supply circuit breaker(s). A traditional load-shed system is not practical on the drill-ship because the majority of the electrical load results from the ship’s thrusters and the drilling power system.

Fortunately the drilling loads and the ship’s thrusters are controlled by Variable Frequency Drives (VFD’s). These drives are solid state frequency conversion systems, which can be easily controlled by the power management system. In each case, control signals can significantly reduce the input power demand of a drive in one to five cycles.

After thorough consideration of the power system requirements of the drill-ship, the power management system has been designed to take advantage of the Kongsberg computers and Operator Interface Stations that are to be installed on the drill-ship. The power management system will be integrated into the vessel's Integrated Control and Monitoring System. It will employ this equipment to fulfil its functions. The power management system will operate as detailed in this specification to avoid electrical system blackouts.

To accomplish this task the control system will perform the following functions:

1. Monitor the condition of each diesel engine/generator set and start up or shut down specific generator sets in response to alarm conditions of parameters measured and monitored by the system.

2. Control the load sharing of the generator sets on-line.

3. Monitor the load situation of the grid to initiate starting and to recommend stopping of engine/generator sets as required to maintaining sufficient power to the electrically driven equipment. This is accomplished while at the same time not allowing unnecessarily high amounts of power to be connected to the grid.

4. Provide system anti-blackout protection:

> *a) Reduce/limit drilling facility (loads) as required to prevent overload of the grid in the event of a trip of a generator or the addition of critical loads causing a shortage of power on the grid, (Drilling System scope)*
>
> *b) Monitor the health of the electrical distribution system and the system frequency to prevent global system blackout in the event of a bus fault on any of the electrical system switchboard sections by opening bustie circuit breakers, and*
>
> *c) Initiate specific load management actions at three separate under frequency levels.*

5. Provide blackout restart of the power system in the event of a total system blackout.
6. Maintain sufficient power at all times for the operation of the ship thrusters to maintain vessel position.

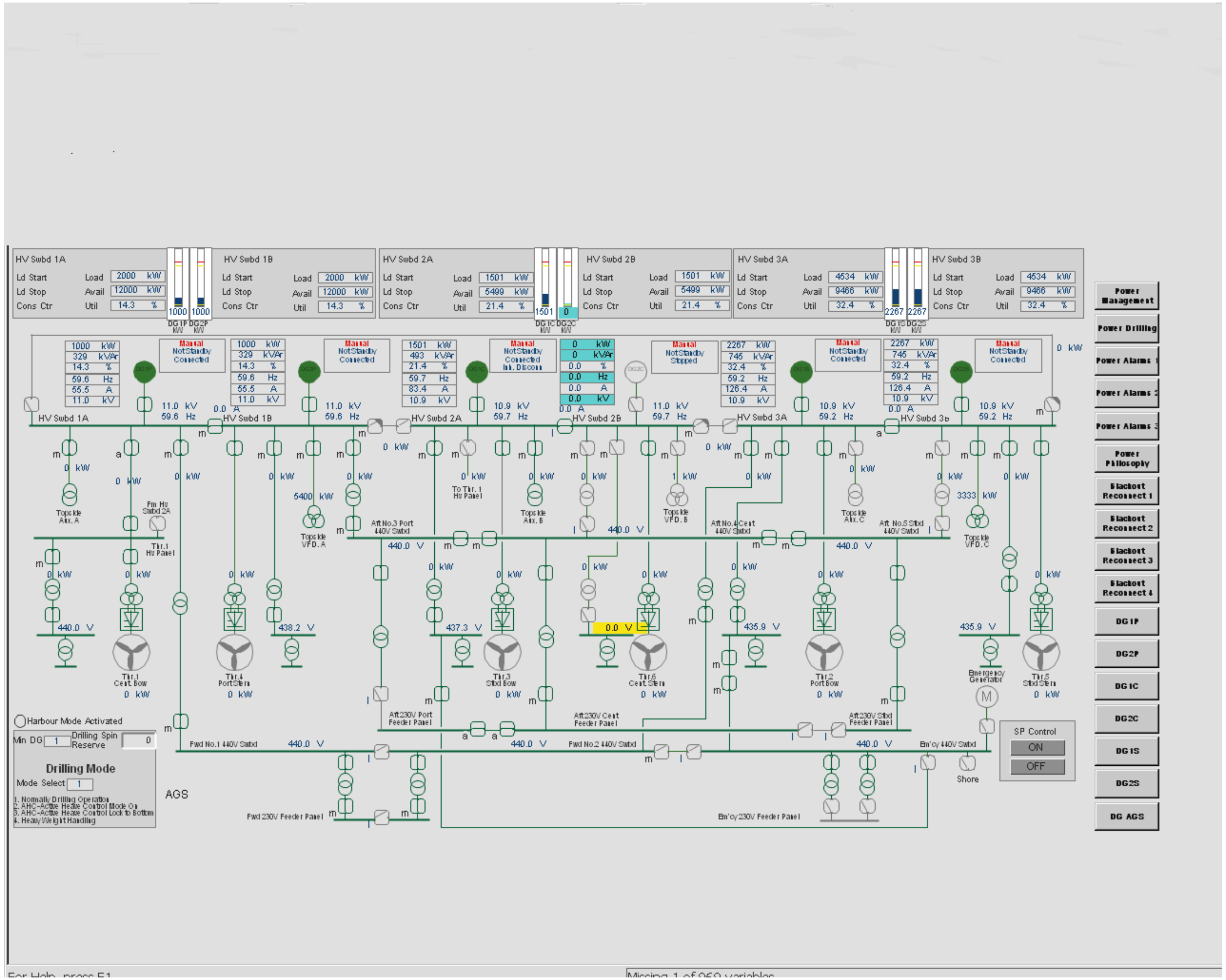
2. The Electric Power Plant

The electric power plant consists of 6 main diesel generators 16V32/40 (11kV) and the rated power of main diesel generators are 7.0 MW. The main generators and 11kV switchboards are located in the aft engine rooms port, centre and stbd.

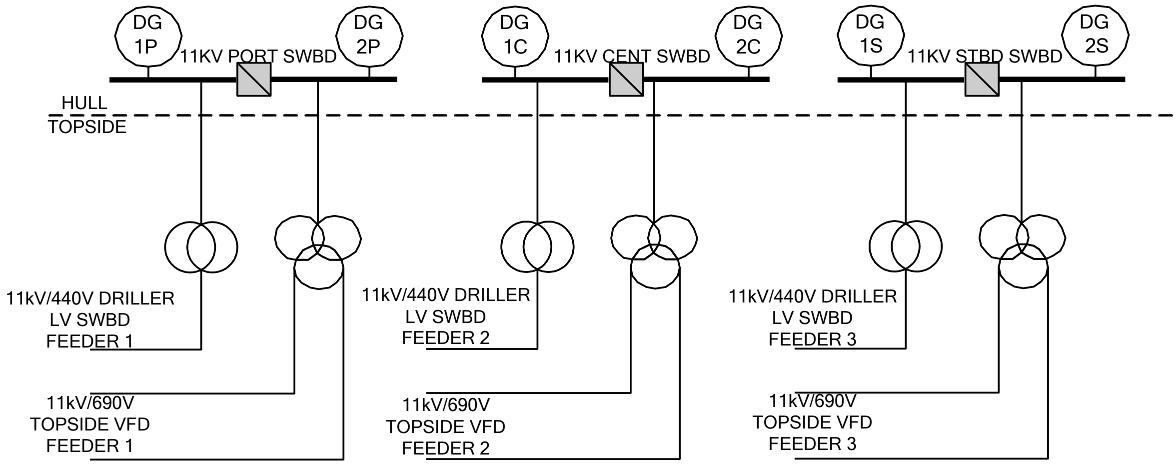
The 11kV plant is divided in 6 bus sections divided in 3 switchboard rooms (port, centre, and starboard switchboard). Each bus section is fed from 1generator, and all consumers are supplied from these bus bars. The port #1 11kV switchboard feeds Thruster #1 and port #2 11kV switchboards feeds Thruster #5. The centre #1 11kV switchboard feeds Thruster #2 and centre #2 11kV switchboards feeds Thruster #6. The starboard #1 11kV switchboard feeds Thruster #3 and starboard #2 11kV switchboard feeds Thruster #4. The failure of any one of the 11kV switchboards will result in the failure of one thruster. These thrusters will be supplied by its associated 11kV switchboard. All switchboards can be interconnected by bus tiebreakers. The operator should decide whether the switchboards will be operated in six, five, fore, three, two split switchboards or closed ring, depending on the situation at that time. For this project the preferable operation philosophy will be running in closed ring.

To prevent system blackouts generator protection system hardwired protection in the HV switch board will open the tie breakers in the event of detection of short-circuit, and if the short-circuit is still present, open the generator breakers. There will also be zone protection for each six switchboard since the system will be operating in closed ring. For detail information about the zone protection, see documentation form HV switchboard maker.

Directional over current relay in bus tiebreakers in the six adjacent switchboards will see the fault (together with all generator relays connected). This bus tiebreaker relay will trip the bus tie connected to the faulty switchboard within 800 ms (Isolate the faulty switchboard).The generator relays connected to the faulty bus will also give trip signal to the two bus ties at the same time. Generator connected to the isolated faulty part will trip in 1 second.


HV Swbd 1A
HV Swbd 1B
HV Swbd 2A
HV Swbd 2B
HV Swbd 3A
HV Swbd 3B
Ld Start
Ld Stop
Cons Ctr
Load
Avail
Util
Harbour Mode Activated
Drilling Mode
Mode Select
AGS
SP Control
ON
OFF
Shore
Power Management
Power Drilling
Power Alarms 1
Power Alarms 2
Power Alarms 3
Power Philosophy
Blackout Reconnect 1
Blackout Reconnect 2
Blackout Reconnect 3
Blackout Reconnect 4
DG 1P
DG2P
DG 1C
DG2C
DG 1S
DG2S
DG AGS
For Help, press F1

Port, Centre and Stbd 11kV switchboard provides two feeders to topside for drilling. The two feeders provide power to topsides though two transformers. The first transformer is a two winding transformer providing 690V for drilling drives and the second transformer is provides 440V for drilling distribution.



The thruster frequency converters (ABB ACS6000) contain power loss function, which can handle short networks breaks preventing the thrusters from under voltage fault. The supply breaker of the converter will be kept closed. If the internal DC voltage drops the converter will stay connected with the motor and use the inertia of the motor to generate power back to the drive. This will keep the DC link charged and decelerate the motor. If the voltage returns within 3 seconds, the drive will accelerate the motor back to requested speed. If the voltage does not return within 3 seconds, the supply breaker will trip and this will also cause the drive to trip.

The motor must run at minimum 10% speed for the drive to be able generate sufficient amount of power to stay charged.

2.1.1 *List of main consumers:*

Description	Nominal Power	Variable / fixed load	Bus Section, Switchgear Unit No.
No.1 Thruster	5500 kW	Variable	Port no.1 11kV Swbd
No.2 Thruster	5500 kW	Variable	Centre no.1 11kV Swbd
No.3 Thruster	5500 kW	Variable	Stbd no.1 11kV Swbd
No.4 Thruster	5500 kW	Variable	Stbd no.2 11kV Swbd
No.5 Thruster	5500 kW	Variable	Port no.2 11kV Swbd
No.6 Thruster	5500 kW	Variable	Centre no.2 11kV Swbd
Firewater Pump No 2	450 kW	Fixed	Port Switchboard
Firewater Pump No 3	450 kW	Fixed	Starboard Switchboard
Drilling Drives SWBD A		4181 kW	Port Switchboard
- Top Drive	1 of 1000 kW		
- Active Heave Drawwork	2 of 1119 kW		(Main)
- Active Heave Drawwork	2 of 858 kW		(Aux)
- Mud Pumps	4 of 858 kW		
- Cement Pump	1 of 858 kW		
Drilling Drives SWBD B		4475 kW	Centre Switchboard
- Topdrive	1 of 1000 kW		
- Active Heave Drawwork	2 of 1119 kW		(Main)
- Active Heave Drawwork	2 of 858 kW		(Aux)
- Mud Pumps	4 of 858 kW		
Drilling Drives SWBD C		4181 kW	Starboard Switchboard

- Topdrive	2 of 1000 kW		
- Active Heave Drawwork	2 of 1119 kW		(Main)
- Active Heave Drawwork	2 of 858 kW		(Aux)
- Mud Pumps	2 of 858 kW		
- Cement Pump	1 of 858 kW		

2.1 Operation Modes

Six operational modes are available for used for the power generation. Transfer from one mode to another is done by remote operation of the breakers from PMS.

Note. Changing the bustie configuration can only be done in compensated droop mode.

Some of the most comment operation mode will be shown below.

2.1.1 Open ring operation mode

Three11kV main switchboards are connected by bus-transfer breakers. See figure below for an example of “Open Ring Mode”.

There are other configurations that are considered as open ring mode.

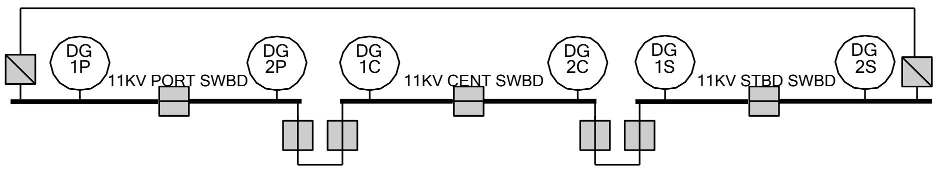


Figure 2-1 Open ring mode

2.1.2 Two split operation mode

In this mode two of 11kV switchboards are connected by the bus-transfer breakers. Port SWBD No.1&2 connected to Centre SWBD No.1. See figure below for an example of “Two Split Mode”.

There are other configurations that are considered as “Two Split Mode”.

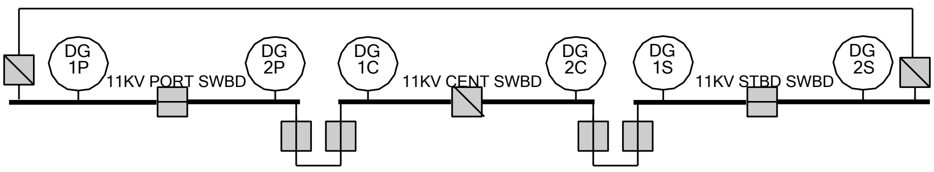


Figure 2-2 Two split operation mode

2.1.3 Three split operation mode

Three 11kV switchboards are operated individually.

Port SWBD, Centre SWBD and Stbd SWBD are split.

There are other configurations that are considered as "Three Split Mode".

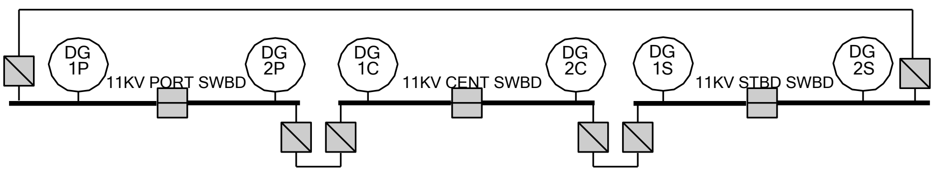


Figure 2-3 Three split mode

2.1.4 Closed ring operation mode

Three11kV main switchboards are connected by bus-transfer breakers. See figure below for an example of “Closed Ring Mode”.

This will be the preferable mode for this project.

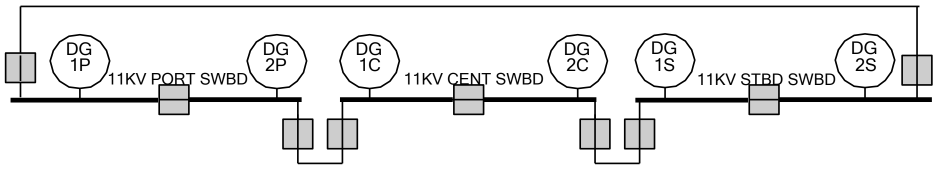


Figure 2-4 Closed Ring mode

2.2 Generator Control and Monitoring

2.2.1 Generator

Monitoring

- Generator Voltage
- Generator Current
- Generator Frequency
- Generator Active Power
- Generator Reactive Power
- Generator Winding U/V/W Temperature
- Generator Cold Air Temperature
- Generator Hot Air Temperature
- Generator ND-End Temperature
- Generator D-End Temperature
- Generator Water leakage
- Generator Synchronization Failure
- Generator AVR Fault
- Generator ND-End LO Level
- Generator D-End LO Level
- AGS. Se separate chapter

2.2.2 Generator Breaker & Measurement and Synch Cubicle

Control

- Breaker Open
- Breaker Close
- Increase Speed
- Decrease Speed
- Set Droop Mode
- Set Isochronous Mode

Monitoring

- Closed
- Opened
- Ready
- Breaker tripped (short pulse)- no manual reset necessary
- Breaker tripped and blocked (steady pulse + Not ready) - manual reset must be done before further operation
- Earth switch closed
- Synch fault
- Current (see next chapter)
- Generator Droop Mode Feedback
- Generator Isochronous Mode Feedback

Interlocks in PMS

Breaker can be operated when:

- Breaker is ready
- Not tripped and blocked

Protection

All transfer breakers are operated by protection relays to isolate bus sections in case of a fault on one of the bus sections.

Flow Control

In case of Breaker Opened/Closed Feedback is wrong, flow control has been added in PMS. For Generator Breaker, Generator Active Power and Breaker Feedback signals are combined to define the status of breakers.

2.2.3 Generator Breaker Connection

When the diesel engine is started and generator voltage is established, the generator can be connected to the switchboard. PMS does not control speed. PMS sends “connect” request to switchboard and ABB synchronizer checks and sync the generator. Bus-tie breaker has no sync unit in SWBD, only synch-check is done by ABB.

The synchronising unit ensures that an incoming generator always will run faster than the net in order to avoid trip by reverse power.

If the start of the diesel engine is caused by an automatic start request from the PMS and the synchronising unit will be activated automatically and the generator will connect without operator intervention. The “close breaker” signal will be initiated by the PMS. The speed adjustment for closing the breaker is controlled by ABB.

When connecting in Isochronous mode Symap will take care of synchronisation and connecting of breaker.

If the PMS are in Droop mode then the PMS will control the speed command to the engine.

In the event that closing of generator breaker to dead bus is required, the synchronising unit will be bypassed (by internal HV switchgear logic). The signal is interlocked by a blackout detection unit in the HV switchboard. PMS will then only send “close breaker”.

Synchronising time out alarm is given if breaker is not closed within 60 seconds (10 seconds during blackout).

Start up synchronizing time shall not be more than 40 seconds when related sub systems are available.

In case the Generator Breaker has mechanically problem and remains connection after Generator Shutdown, PMS will trip the busties between the fault switchboard and others. If busties are open before this scenario, they will be interlocked to close.

2.2.4 Breaker disconnection:

Droop Mode:

When a *disconnect* command is given on the operator station PMS will perform an automatic load reduction, provided that the generator load-sharing mode is either SYMMETRIC or ASYMMETRIC. The PMS will be giving **lower speed** pulses to the governor. When generator load is less than 10 % (adjustable parameter) the PMS will open the generator circuit breaker.

If the stop of the generator is caused by an automatic stop request (load dependent stop or from engine change-over system) generator downloading and breaker Open will be performed automatically, without operator intervention.

Isochronous Mode:

When a *disconnect* command is given on the operator station the PMS will send unload signal to the Symap-system from Doosan who will control the load down and the PMS will send “open breaker” when generator load is less than 10%.

If the stop of the generator is caused by an automatic stop request (load dependent stop or from engine safety system), the PMS will send unload signal to the Symap-system from Doosan who will control the load down and the PMS will opening of generator breaker will be done automatically, without operator intervention.

2.2.5 Generator protection system

Generator overload trip functions are provided in the HV switchboards. The Main Generator set protective relays have the following settings:

- Over current Limit 1 120% , no trip
- Over current Limit 2 155% at 1 seconds
- Directional over current 140% at 1.5 seconds
- Active power limit for reverse power 3.4% at 9 seconds
- Over frequency Limit 1 63 Hz at 5 seconds
- Under frequency Limit 1 54 Hz at 3 seconds
- Under voltage
- Differential protection
- Phase unbalance
- Earth fault
- Field (AVR) failure
- Short circuit on bus bar

2.2.6 Interlock of generator breaker operation:

The generator breaker is blocked for closing from PMS in the event that any of the following conditions are present:

Generator breaker interlock:

Description	Tag	Limit	Remark
11kV BUS BAR EARTH FAULT/SHORT CIRCUIT	XA-032165		Open=Fault
BUSBAR EARTH SWITCH STATUS	XI-032166		Closed=Earthed
GEN BREAKER TRIPPED AND BLOCKED	XA-031106		Also start block, Open=Tripped
GENERATOR BREAKER NOT REMOTE READY	XI-031103		Open=Breaker Not Ready Or breaker in local mode
HV SWBD 1 INSULATION LEVEL LOW	XI-032167		Open=low
HV SWBD 1 DC 110V FAILURE	XA-032164		Open=fail
MGE GOVERNOR (MAJOR) FAIL ALARM	XA-011104**A**		Open=fail

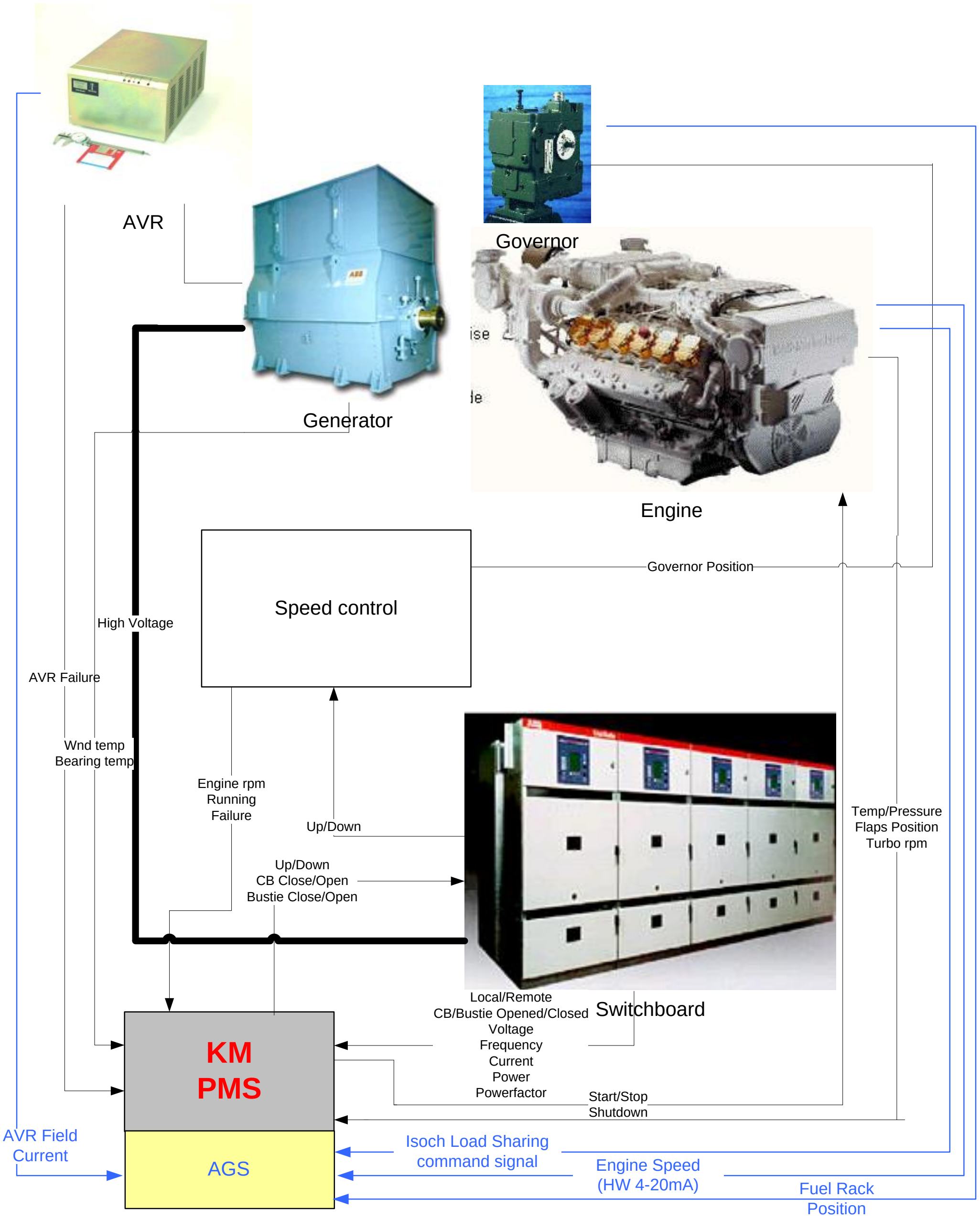
Breaker will also trip/open if a failure is received from Governor Major (XA-013104) during operation. This to prevent other connected generators from taking reverse current if one generator is running with over speed.

The PMS will be toggle to droop mode if a failure is received from Governor Minor during operation. Then the PMS will be in control and can take necessary action.

The generator breaker is blocked for opening from PMS in the event that any of the following conditions are present:

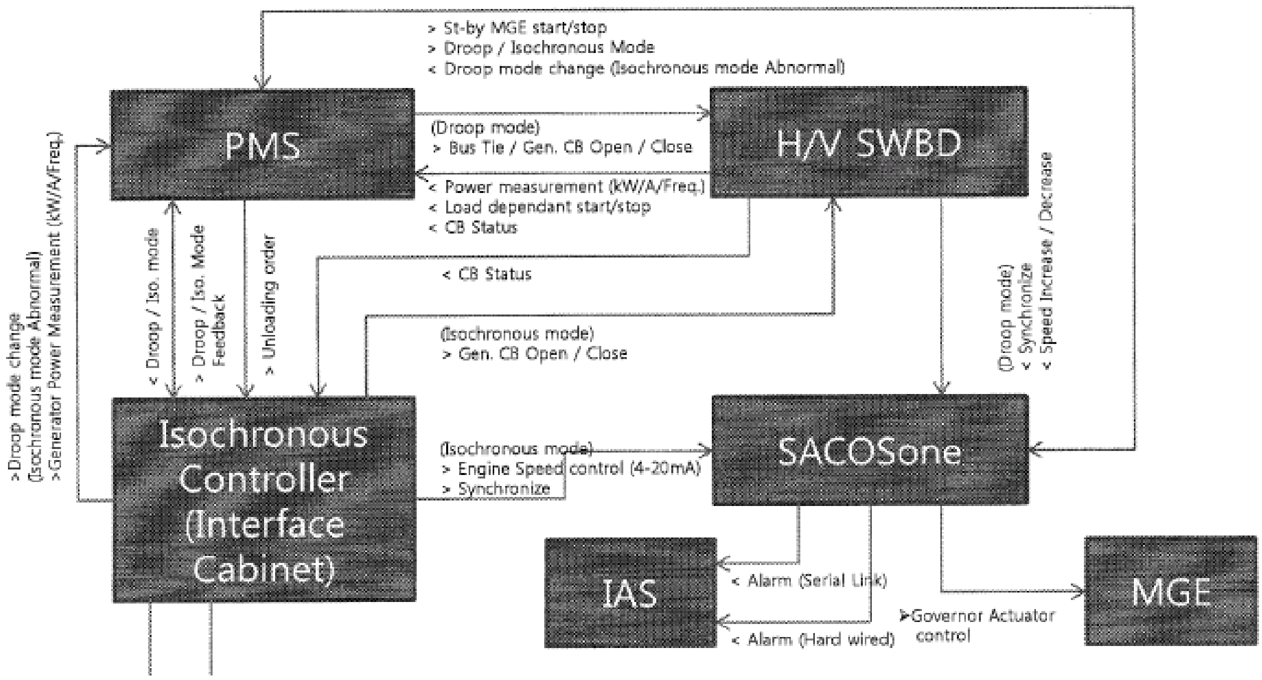
- If this is the last connected generator
- If disconnection of generator will cause the load on the remaining generators to exceed 100% (adjustable parameter)

2.3 General overview of the system



Note: AGS is utilizing the existing signals interfaced to/from PMS. The additional AGS specific signals are indicated in blue.

[Isochronous / Droop mode control]



2.3.1 Generator standby selection

The starting and stopping priority of the generators is determined by selecting the generator standby order: *standby 1, standby 2, …, standby 6*.

The generator with the lowest standby order is the first to start and the last to stop.

If two or more generators are set up with the same stand by number, the generator with the lowest generator number will start first and be the last to stop.

In split modes, the generator with the lowest standby number on each switchboard segment will start first. If segments are connected like in 2 split mode, the generator with the lowest stand by number on the two connected segments will start first. The standby numbering can still be from 1 to 6 even if the switchboards are split.

The operator can assign standby numbers according to the current switchboard configuration.

Standby numbering can be changed by the operator in order to balance the running hours for all generators.

Standby start can be caused by any of the following conditions:

- Load dependent start (Ref. 2.3.2 Load dependent standby start & stop)
- Black out (Ref. 2.7 Blackout restart)
- Start attempt of heavy consumer (Ref. 2.3.7 Start Blocking of Heavy Consumers)
- Safety system of any connected generator activated (Ref. 3.4.1 Safety Stop – Shutdown, 3.5 Diesel Generator – Alarm Start)
- Loose the power consumed signal form drilling (Ref. 2.5.4 Power Limiting – Drilling)
- Low frequency (Ref.2.5.6 K-Chief blackout prevention)
- Fault on generator or starting generator (Ref. 3.5 Diesel Generator – Alarm Start)
- Active AGS trip of generator will start all standby generators (even in split bus) (Ref. 2.6Advanced Generator Supervisor (AGS))

Normal stop of standby generator can only be caused by load dependent stop.

A generator which is in *manual* mode (not Standby selected) will not be affected by the standby start/stop system.

The load dependent start and stop function and generator start by start attempt of a heavy consumer can be switched off on the PMS Mimic.

When a generator set as standby, after disconnect, it will go to cooling down and stop process directly. If operator wants to start it during stopping, operator can use “Start” in operator menu.

When a generator set as no standby or manual, after disconnect, the generator will keep running.

Note: When generator sets to Standby in PMS, Doosan engine will maintain standby condition.

2.3.2 Load dependent standby start & stop

Load dependent start/stop is always updating the actual load on each main generator and calculates available power. Each start-up function has adjustable time delay.

The K-Chief Power Management System will perform automatic start of standby generator when the percentage load of the generators exceeds a pre-set level.

LD Start:

If one generator is connected to the bus bars and the actual power exceeds e.g. 85% (surplus power is below 15%), the standby generator shall start up and be synchronized to the bus bars. If the total load on both generators exceeds 85%, the 3rd generator shall start up and be synchronized to the bus bars. In the same way, the load dependent start automatics will start up 4th, 5th and 6th generator if available power decreases below a certain limit, which can be programmed and adjusted in the generator power automation system by advanced user.

LD Stop:

If three generators are connected to the bus bars and surplus power for the last 15 minutes has been more than e.g. 46% of each generator, the last connected generator will stop and the total load on the remaining two generators will increase to 69%.

If the load still drops below 32.5% of total load for each of two remaining generators (surplus power 67.5%) one of the generators shall stop, and the total load on the remaining generator shall increase to about 65%. This mode will be allowed to set for different power management during in DP mode.

The load dependent start/stop function is based on the percentage load of the connected generators. For starting, two sets of values with different time delays are defined. An automatic load dependent stop (provided that the function is enabled) is initiated if the load of the remaining generators after stop will be less than specified Stop limit value.

In the diagram the following standby selection is foreseen:

Gen.1 Port 7.0 MW generator:	Standby sequence No. 1
Gen.2 Port 7.0 MW generator:	Standby sequence No. 6
Gen.3 Cent 7.0 MW generator:	Standby sequence No. 2

Gen.4 Cent 7.0 MW generator: Standby sequence No. 5

Gen.5 Stbd 7.0 MW generator: Standby sequence No. 3

Gen.6 Stbd 7.0 MW generator: Standby sequence No. 4

Note: In DP mode and ring connection the PMS will set the min amount of generators to 2. This will have a higher priority then the LD stop and therefore keep the amount of generator to minimum 2. This also applies for drilling mode 1 to 4.

Load dependent start / stop function:

Number of MGEs connected	Start limit 1	Delay time	Start limit 2	Delay time	Stop limit	Delay time
1	70%	30 s	82 %	7 s	-	-
2	73 %	30 s	82 %	7 s	65%	15min
3	76 %	30 s	82 %	7 s	69%	15min
4	78 %	30 s	82 %	7 s	72%	15 min
5	80 %	30 s	82 %	7 s	76%	15 min
6	-	-	-	-	79%	15 min

To enable load dependent start / stop the functions *Load dependent start* and *Load dependent stop* must be switched on. Further, some or all generator must be set to *standby* operation. In the event that the power plant is running in split busbar configuration, the load dependent start / stop functions will operate as independent power systems.

Load Settings for start and stop of Gensets.				
When all the tie breakers are Closed				
Settings for standby start				
Current Gensets	Load setting for standby start	No of Gensets after standby start	Load on each genset	Time setting, Second

Load Settings for start and stop of Gensets.				
1	70%	2	35.00%	30s /7s
2	73 %	3	48.67%	30s /7s
3	76 %	4	57.00%	30s /7s
4	78 %	5	62.40%	30s /7s
5	80 %	6	66.67	30s /7s
6				
Settings for Stopping One Genset				
Current Gensets	Load setting for Stopping One Genset	No of Gensets after stopping one.	Load on each remaining gen sets	Time setting, Minutes
6	65.83%	5	79.00%	15
5	60.80%	4	76.00%	15
4	54.00%	3	72.00%	15
3	46.00%	2	69.00%	15
2	32.50%	1	65.00%	15
1				

2.3.3 Load sharing& Net Frequency Control

The load sharing can be run in two different modes, Isochronous and Speed Droop. Load sharing mode can be selected by means of “soft buttons” on the PMS Mimic. To avoid a mix of load sharing modes on the same switchboard there is no individual mode selector on each generator, but one button for each switchboard. If two or more switchboards are interconnected, operation of button on one switchboard will change mode for all connected switchboards.

Isochronous load sharing is from PMS's point of view considered as "external control", i.e. no speed control from PMS. When Droop Mode is selected, PMS is adjusting the speed of the engine by means of raise/lower pulses to the governor.

For this project the operation in DP mode will mainly be isochronous mode.

Note. When the operator is setting up the switchboard or after blackout restart the PMS will be in Droop mode until the operator are changing it to Isochronous mode.

In case of any load sharing failure the PMS will switch to droop mode.

2.3.4 Isochronous Mode

Isochronous mode is defined as follows: "A unit with zero droop is isochronous".

A generator set operating in isochronous mode will maintain the same set frequency regardless of the load it is supplying except for momentary speed changes due to load changes, up to the full load capability of the generator set.

Isochronous load sharing will perform automatic proportional division of the total load between generator sets while maintaining a fixed frequency on the bus.

All generators in the system will maintain equal percentages of their full load capacity.

When selected to isochronous the Symap will accomplish isochronous load sharing for the active generator sets.

The Symap compares the load on its generator to the load on other generators in the system, and applies the governor to increase or decrease engine fuel to maintain the generators proportional share of the total system load.

Note: Individual feedback on generators for Isochronous / Droop mode.

If one DG loose Isochronous status signal. The PMS system will switch to droop mode.

The PMS monitors the load of all connected generators and will, in isochronous mode, give an alarm if the load between the connected generators deviates from a defined limit.

For selection of mode: Individual pulsed output for droop and isochronous.

The PMS system will toggle the different switchboards automatically if operated in remote mode. If one switchboard is operated in isochronous mode and one in droop mode and they are connected together, the PMS will toggle automatically both switchboards over to droop mode.

There will possible to run the generator in Asymmetric mode in isochronous mode.

2.3.5 Speed Droop Mode

In this mode the PMS supports a number of load sharing options:

- Symmetric load sharing
- Asymmetric load sharing
- Fixed load
- Manual load sharing

The above load-sharing functions can be selected individually for each generator. Load sharing is based on active power (kW) measurements.

For load sharing and net frequency control, speeds increase / decrease signals (pulses) are sent to the Woodward EM300 speed governor via the 11kV switchboard. The frequency of the 11kV switchboard will be maintained at 60 Hz when the connected generators have been selected to symmetric or asymmetric load sharing. This will be controlled by the PMS even if the governor is set up with a speed droop of 4%. A small dead band is foreseen.

The PMS system will toggle the different switchboards automatically if operated in remote mode. If one switchboard is set to local mode (isochronous mode) and one in droop mode, and they are connected together, the PMS will not be able to toggle automatically the switchboard which is in local mode, over to droop mode since PMS don't have any control over a switchboard in local mode.

Programmers note:

Speed droop is expressed as the percentage reduction of speed that occurs when the generator load increases from no load to rated load.

If all generator sets in the system have the same droop setting, they will each share load proportionally. The amount of load will depend on their speed settings.

Normally the speed droop is set to 4%, i.e. the engine speed will decrease by 4% between no load and full load.

For example, if the frequency is 62Hz at no load, the frequency at full load should correspond to about 59.5Hz.

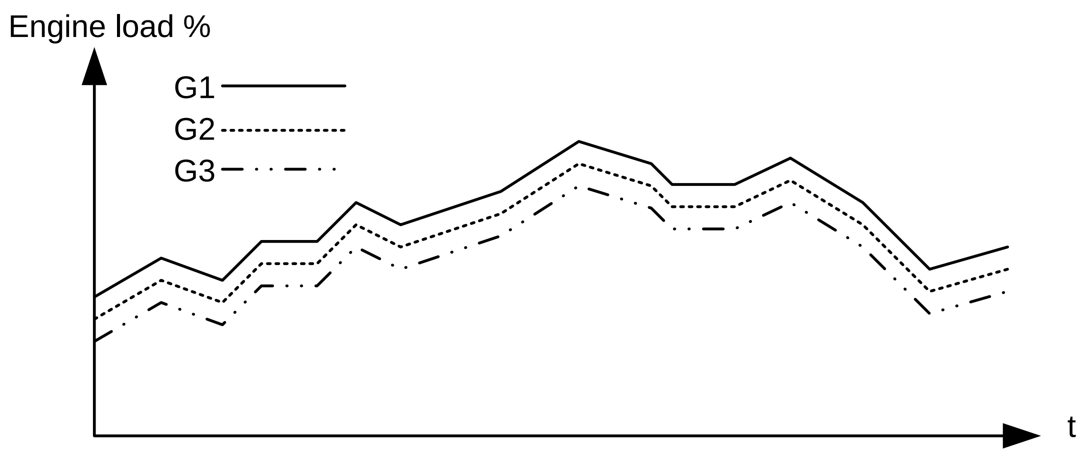
In the event of split bus bar configuration (bus bar breakers are open) the load sharing will be performed individually for each bus bar as if there where two/six independent power management systems.

In the following cases, PMS will set generators to DROOP mode:

- Isochronous mode fail (symap controller fail, CANbus communication fail)
- Load Reduction Request
- Change Over Request (Mechanical Problem)
- Shutdown
- Load Sharing Failure
- HV Bustie Close Command (will switch back to ISO mode after connected or 60sec timeout)
- Blackout Occurs
- Standby DG Connect (will switch back to ISO mode after connected or 60sec timeout)

2.3.5.1 Symmetric load sharing

In this mode, the load of the generators running in parallel will be equal. A small dead band, 1 % of rated power, is foreseen. The figure below illustrates the symmetric load sharing.



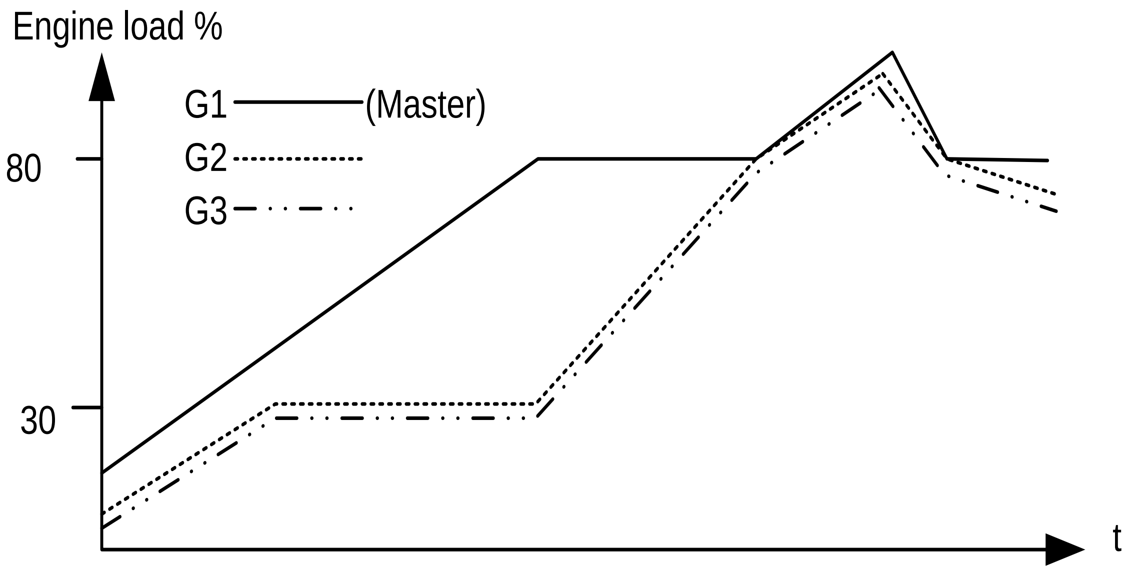
2.3.5.2 Asymmetric load sharing

The intention of the asymmetric load sharing function is to burn off carbon accumulated during engine low load operation.

In asymmetric load sharing one generator will be loaded to 80 % (master) while the other generators (slaves) will share the remaining load. After 4 hours, another generator will be selected as master.

The master generator is selected automatically in same sequence as stand-by order.

In the event that the load on the slave generator(s) falls to 30 % and the total power demand further decreases, load will be taken off the master generator. If the total load on the net exceeds 80 % or is less than 30 %, the generators will be load shared symmetrically. The setpoints and changeover period can be adjusted by authorised personnel (password protected).



The figure above illustrates the asymmetric load sharing.

2.3.5.3 Fixed load

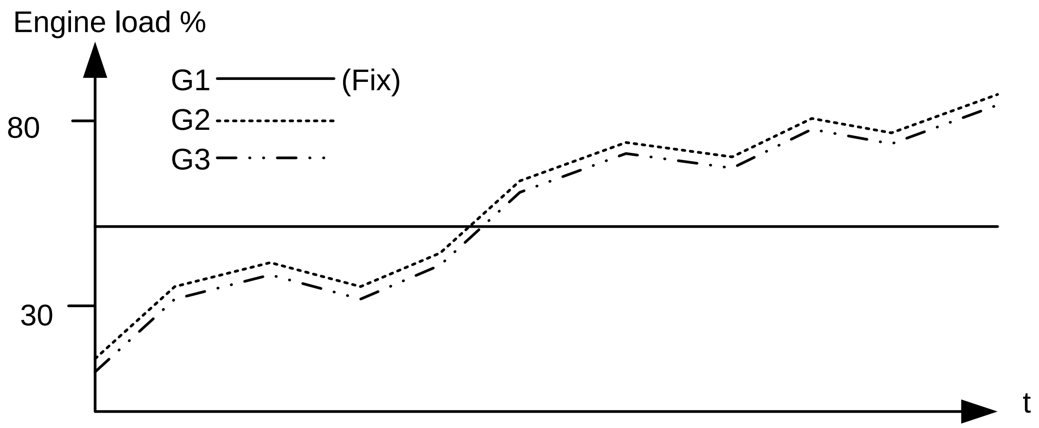
For maintenance purposes it is sometimes required to run a generator with steady load. This can be achieved by selecting the generator to fixed load sharing. The set value is selected by the operator and maintained by the PMS. Fixed load mode can not be selected when the generator is in standby mode. If the generator is in stand by mode, entering fixed mode will take the generator out of stand by mode. There must be at least 2 generators running on a switchboard or connected switchboard segments in order to enter fixed load mode. This means that in order to run in fixed mode in 3-split operation mode, both generators on the switchboard segment must be running.

If a generator is selected for Fix load and the total load on the other generators is above 100%, then the Fix load function will be bypassed and the generator starts to take load to prevent overload on the other generator.
When the one generator is set to fixed mode and the reminding generators are running in symmetric mode and the load drops below 15%, then the generator running in fixed will be forced over to symmetric mode to prevent the reminding generator going in to reverse power. The operator has to manually change the generator back to fixed mode when the load is above 15% load.

Fixed load mode can only be selected when the generator has a load more than 15%.

For the DP systems power calculation and PMS load reduction, the max power is the same as the generator is currently loaded with. If the engine load increases the new load will go in as the maximum available load for the engine in the internal calculation

When generator is in Fixed Mode, no available power will be calculated on the whole power plant. The capacity of generator is 100%. It is possible to have more than one generator to be set in Fixed Mode.



NOTE: This mode is a maintenance purposes. The generator will not be available for LD start/stop scenarios and blackout restart.

2.3.5.4 Manual load sharing

When a diesel generator is selected to manual load sharing, the operator can give speed increase / decrease signals to the speed governor directly from the operator station. In this mode, the PMS performs no active load sharing of the generator.

Manual load sharing can not be selected when the generator is in standby mode.

If the load increases on the bus, then this engine that's run in manual will take load just as all the other engines, but a little bit slower since its only following the other engines because of the droop.

For the DP systems power calculation and PMS load reduction, the max power is the same as the generator is currently loaded with. If the engine load increases the new load will go in as the maximum available load for the engine in the internal calculation.

When generator is in Manual Mode, no available power will be calculated on the whole power plant. The capacity of generator is 100%.

NOTE: This mode is a maintenance purposes. The generator will not be available for LD start/stop scenarios and blackout restart.

2.3.6 Net frequency control

The frequency of the 11 kV switchboards and 440 V switchboards will be maintained at 60 Hz when the connected generators have been selected to symmetric or asymmetric load sharing. A small dead band of 0.1 Hz is foreseen.

The PMS will automatically open the tie breakers between the 11 kV bus sections (port/centre and/or centre/stbd) if frequency below 54 Hz is detected for a duration of 3 seconds. Failure of the frequency transducer shall not initiate the bus segregation function.

When the feedback of switchboard Frequency is wrong (measurement failure) and the deviation to other switchboard is higher than 3Hz (<57Hz or >63Hz), high deviation alarm will be generated after 15sec.

When the feedback to switchboard Voltage is wrong (measurement failure) and the deviation to other switchboard is higher than 10%, high deviation alarm will be generate after 15 sec.

- Under Frequency Protection on ABB Switchboard

In the event of a sudden load increase which generators is unable to handle (such as power disruption or PMS error/fault) a under frequency routine will activate to help stabilize the power network. The network frequency is monitored via a separate power transducer measuring directly on the incomer AC side. Depending on running configuration such as DC-bustie and DSU operation the relevant AC bus frequency is monitored.

If the net frequency drops below 57Hz (tuneable) the under frequency routine is activated and power is limited instantly to 2/3(66%, tuneable) of current load.

The fixed limitation based on previous present load will remain until network frequency drops below 56Hz (tuneable). From this value limitation will be proportional to net frequency reaching full reduction (minimum power limit value) at 52Hz (tuneable).

The frequency routine will deactivate after frequency has been above 57Hzfor over 1 minute (tuneable).

2.3.7 Start Blocking of Heavy Consumers

To prevent overload of the power generation plant, the PMS contains start blocking of the following consumers.

To prevent overload of the power generation plant, the PMS contains start blocking of the following consumers.

Port side (bus bar 1):

	No	Description	Blocking limit	No of diesel required	Time-out
No Pre-Mag Failure	1	Thruster 1	500kW	1	120 sec.
	2	Drilling Port	1000kW	1	120 sec
Pre-Mag Failure	1	Thruster 1	500kW	2	120 sec.
	2	Drilling Port	1000kW	1	120 sec

Port side (bus bar 2):

	No	Description	Blocking limit	No of diesel required	Time-out
No Pre-Mag Failure	1	Thruster 4	500kW	1	120 sec.
	2	Drilling VFD Port	1000kW	1	120 sec
Pre-Mag Failure	1	Thruster 4	500kW	2	120 sec.
	2	Drilling VFD Port	1000kW	2	120 sec

Centre side (bus bar 1):

	No	Description	Blocking limit	No of diesel required	Time-out
No Pre-Mag Failure	1	Thruster 3	500kW	1	120 sec.
	2	Drilling Centre	1000kW	1	120 sec
	3	Thruster 1	500kW	1	120 sec.
Pre-Mag Failure	1	Thruster 3	500kW	2	120 sec.
	2	Drilling Centre	1000kW	1	120 sec
	3	Thruster 1	500kW	2	120 sec.

Centre side (bus bar 2):

	No	Description	Blocking limit	No of diesel required	Time-out
No Pre-Mag Failure	1	Thruster 6	500kW	1	120 sec.
	2	Drilling VFD Centre	1000kW	1	120 sec
Pre-Mag Failure	1	Thruster 6	500kW	2	120 sec.
	2	Drilling VFD Centre	1000kW	2	120 sec

Stbd side (bus bar 1):

	No	Description	Blocking limit	No of diesel required	Time-out
No Pre-Mag	1	Thruster 2	500kW	1	120 sec.

Failure	2	Drilling Stbd	1000kW	1	120 sec
Pre-Mag Failure	1	Thruster 2	500kW	2	120 sec.
	2	Drilling Stbd	1000kW	1	120 sec

Stbd side (bus bar 2):

	No	Description	Blocking limit	No of diesel required	Time-out
No Pre-Mag Failure	1	Thruster 5	500kW	1	120 sec.
	2	Drilling VFD Stbd	1000kW	1	120 sec
Pre-Mag Failure	1	Thruster 5	500kW	2	120 sec.
	2	Drilling VFD Stbd	1000kW	2	120 sec

The heavy consumer start block function can be switched on / off from operator station. If selected off, the consumers will be started without checking the available power.

Upon a start request from the IAS system, the PMS will check whether the available power is sufficient to allow starting of the electric motor. If not, a standby generator start request is given. When the capacity of the power plant is sufficient and other start conditions are fulfilled, electric motor start order is given. If sufficient capacity is not reached within time out specified time, the motor start order is timed out.

2.4 Bustie / Transformer Breaker Control

Circuit Breaker Control – HV SWBD

All breakers except feeder breakers to Thruster VFD are monitored and controlled by PMS. Thruster VFD feeders are monitored only, control is directly from VFD. All signals are hardwired. Breakers are protected locally in the switchboard by protection relays.

All breakers on HV SWBD are tripped at under voltage.

2.4.1 Transfer breakers (Bustie master/Slave)

There are two methods to synchronize a bus-tie between the HV SWBD's. The different modes are set with a selector switch in the bus bar measuring unit. In "Remote Auto mode" synchronizing command is given from PMS. In "Local Auto" the close command is given from the switchboard front.

The two modes are selected with the selector switch in:

- **HV SWBD 1 (UNIT A08)** for bus-tie between HV SWBD 1 and HV SWBD 2.
- **HV SWBD 2 (UNIT A06**) for bus-tie between HV SWBD 2 and HV SWBD 3.
- **HV SWBD 3 (UNIT A08)** for bus-tie between HV SWBD 3 and HV SWBD 1.

2.4.1.1 Operation criteria when a bus-tie is in remote mode

Remote/Auto (R/A)

When the switch in the measuring unit is set in R/A position, HV SWBD will send a BREAKER REMOTE READY signal to PMS. Then the transfer breakers between the HV SWBD's can be remote controlled by the automation system (PMS). PMS sends a close signal to the bus-tie breakers between the HV SWBD. The synch-check unit compares the voltage, frequency and phase angle and the PMS automatically raises or lowers the engine speed of the connected generators in the respective switchboards in order to obtain speed match. Then both BUS-TIE breakers will close simultaneously. If the close signal from PMS disappears (DO=0) the close command will be aborted, i.e. close command from PMS must be high as long as synch shall be preformed.

The BUS-TIE CB between the main switchboards can be opened/Closed from PMS.

For KM-Drill 8 Project, there are no synchronization units only synchronization checks in busties. If generators are in Isochronize mode, PMS will force them to Droop during busties close period and switch back to Isochronize mode after busties close.

2.4.1.2 |Operation criteria when a bus-tie is in local mode

Local/Auto (L/A)

When the LA/RA switch is set in (L/A) position the breaker is in (L/A) mode. In the L/A mode the HV SWBD Bus-tie's are synchronized/closed by turning the Trip-0-Close switch (Close) to the right. The synch-check unit compares the voltage, frequency and phase angle and automatically raises or lowers the engine speed of the connected generators in the respective switchboards in order to obtain speed match. Then both bus-tie breakers will close simultaneously. The synchronization check unit will be stopped if the selected bus-tie is not synchronized to the network within a given period of time. (90 Seconds)

The BUS-TIE CB can be open by operating the open/trip switch.

Synch-check unit are provided by the switchboard for synchronising the switchboards when there is voltage on both sides. During synchronisation and connection of switchboards both associated bus transfer breakers are to be closed simultaneously after the completion of synchronization. There are two transfer breakers on each switchboard, one master and one slave. Bus transfer synch-check unit equipment will only be installed on the master transfer breaker in each switchboard. A special symbol on the PMS mimic (Yellow Triangle) indicates which breakers that are master. See e.g. figure below.

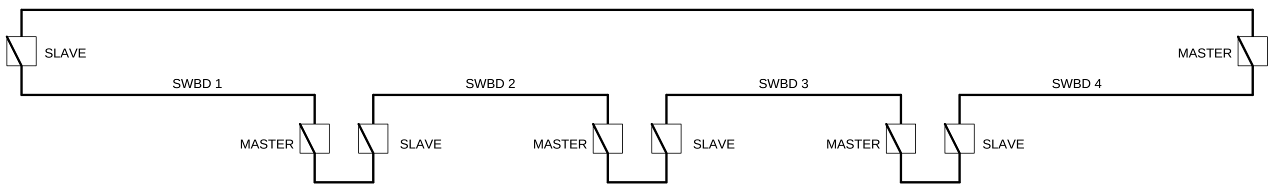


Figure 2-5 Bus transfer breaker configuration

PMS will do speed adjustments until the breaker is closed when droop mode is selected. If isochronous mode is selected, PMS will set the connected generators in droop mode while synchronizing the switchboards. After connection is established or 60sec timeout, PMS will switch mode back to Isochronous.

If one or both sides of the bus tiebreaker are without voltage when the close order is given, the breaker is closed direct.

PMS will generate a discrepancy alarm if the status of the master and slave are different for more than 3 seconds (adjustable).

For KM-Drill 8 Project, there are no synchronization units only synchronization checks in busties. If generators are in Isochronize mode, PMS will force them to Droop during busties close period and switch back to Isochronize mode after busties close or 60sec timeout.

2.4.1.3 Master Transfer Breaker Control & monitoring

Control
- Close command
- Open command

Monitoring
- Closed
- Opened
- Remote – Operation can be done from PMS
- Ready for operation – CB ready for synch, inserted and other criteria. (Available)
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation
- Synch in progress
- Synch fault
- Power (kW)

Interlocks in PMS

Breaker can be operated when:

- Breaker is Ready
- Breaker in Remote
- Not tripped and blocked
- When a bus segment has no generator connected and open bustie will cause blackout, Bustie itself will be interlock to open.

Protection

All transfer breakers are operated by protection relays to isolate bus sections in case of a fault on one of the bus sections. For detailed description see documentation form HV switchboard maker.

Flow Control

In case of Breaker Opened/Closed Feedback is wrong, flow control has been added in PMS. For busties, Bustie Load and Breaker Feedback signals are combined to define the status of breakers.

2.4.1.4 Slave Transfer Breaker Monitoring

This breaker is controlled from IAS through the master transfer breaker. They will be closed or opened simultaneously. The breakers are rated to 816 A, over current limit is set at rated current.

Monitoring

- Closed
- Opened
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation

Interlocks in PMS

NA

Protection

All transfer breakers are operated by protection relays to isolate bus sections in case of a fault on one of the bus sections. For detailed description see documentation form HV switchboard maker.

Programmers note:

This breaker is of type “monitored only”.

2.4.2 Distribution transformer breaker

The breakers are rated to 131 A, over current limit is set at rated current.

Control

- Close command
- Open command

Monitoring

- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no local manual reset necessary
- Breaker tripped and blocked - local manual reset must be done before further operation
- Current
- Power (kW)

In addition to the breaker signals the temperatures for three phases in the transformer are monitored by PMS.

Interlocks in PMS

Breaker can be operated when:

- Breaker is ready
- Not tripped and blocked

Protection

All transformer breakers have protection relays in case of failure. For detailed description see documentation form HV switchboard maker.

2.4.3 Thrusters VFD Transformer breaker

These breakers are controlled by Thrusters VFD, only monitoring in PMS. The breakers are rated to 341 A, over current limit is set at rated current.

Monitoring

- Closed
- Opened
- Ready – breaker ready for operation from VFD
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation
- Current
- Power (power used in power limit function)

Interlocks in PMS

NA

Protection

All Thrusters Transformer feeder breakers have protection relays in case of failure. For detailed description see documentation from HV switchboard maker.

Thruster no. 1 have auto switching function. It can be powered from port (default) or from centre switchboard.

Note: There is interlock on the Thruster no. 1 incomer breaker, meaning only no feeder breaker can be closed (no parallel feeding). This interlock is located in the swbd.

PMS will have a load depending interlock, meaning with load a bow 200kW you will not be able to open the incomer breaker for switching. The operator needs to load down the Thruster nr. 1 below 200kW to be able to switch which swbd the Thruster should be fed from.

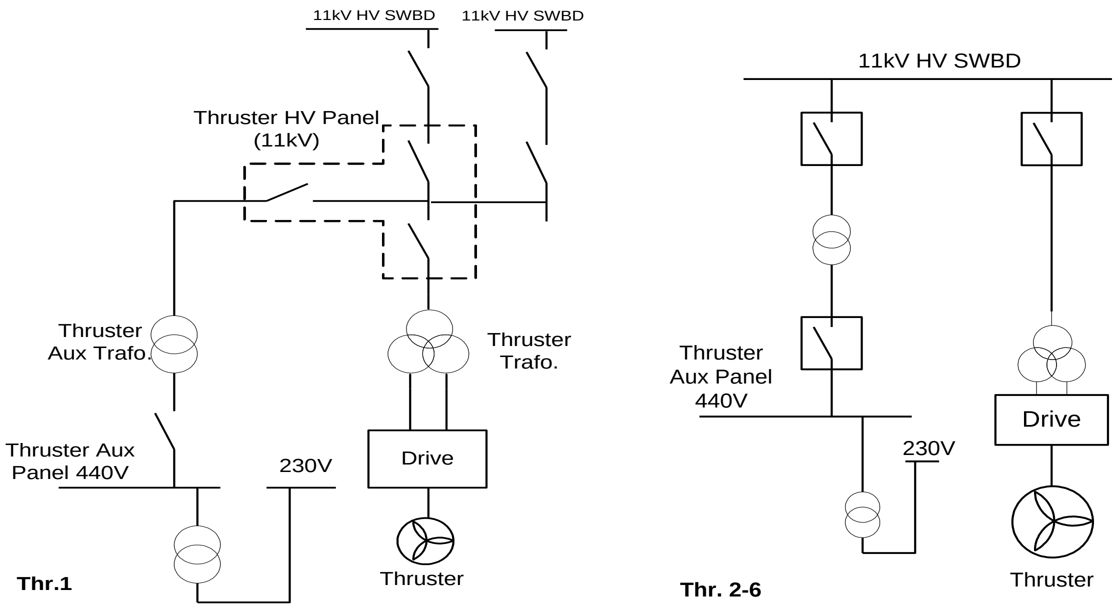


Figure 2-6 Thr. 1 vs Thr. 2-6

Pre-mag Transformers

There is one pre-magnetizing equipment for each thruster Drive. This will decrease the in-rush current during the start phase of thrusters drive. There are 2 signals for this equipment.

“Pre-mag. Failure” (DI): alarm rises up when equipment fails. When the signal rises up, the “Pre-mag Request” will be inhibited. CB will not be closed until there are 2 Generators on the switchboard.

“Pre-mag Request” (DO): usually send the signal during transformer CB closes.

Flow Control

In case of Breaker Opened/Closed Feedback is wrong, flow control has been added in PMS. For Transformer breakers, Transformer Load and Breaker Feedback signals are combined to define the status of breakers

2.4.4 Drilling VFD Transformer breaker

The breakers are rated to 341 A, over current limit is set at rated current.

Control
- Close command
- Open command

Monitoring
- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation
- Current
- Power (power used in power limit function)

In addition to the breaker signals, PMS is monitoring the following signals from the transformer:
- Transformer fan failure
- Transformer winding temperature

Interlocks in PMS

Breaker can be operated when:

- Breaker is ready
- Not tripped and blocked

Protection

All Drilling VFD transformer breakers have protection relays in case of failure. For detailed description see documentation form HV switchboard maker.

Pre-mag Transformers

There is one pre-magnetizing equipment for each thruster Drive. This will decrease the in-rush current during the start phase of thrusters drive. There are 2 signals for this equipment.

“Pre-mag. Failure” (DI): alarm rises up when equipment fails. When the signal rises up, the “Pre-mag Request” will be inhibited. CB will not be closed until there are 2 Generators on the switchboard.

“Pre-mag Request” (DO): usually send the signal during transformer CB closes.

Flow Control

In case of Breaker Opened/Closed Feedback is wrong, flow control has been added in PMS. For Transformer breakers, Transformer Load and Breaker Feedback signals are combined to define the status of breakers

2.4.5 440V Feeder breakers

Control
- Close command
- Open command

Monitoring
- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation
- Current
- Power (kW)

Interlocks in PMS:

Breaker can be operated when:

- Breaker is ready
- Not tripped and blocked

Protection:

All 440V feeder breakers have protection relays in case of failure. For detailed description see documentation form HV switchboard maker.

2.4.6 440V Incomer breakers

Control
- Close command
- Open command

Monitoring
- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation
- Current
- Power (kW)

Interlocks in PMS:

Breaker can be operated when:

- Breaker is ready
- Not tripped and blocked

Protection:

All 440V incomer breakers have protection relays in case of failure. For detailed description see documentation form HV switchboard maker.

2.4.7 440V switchboard interconnection breakers

Control
- Close command
- Open command

Monitoring

- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation
- Current
- Power (kW)

Interlocks in PMS:

Breaker can be operated when:

- Breaker is ready
- Not tripped and blocked

Protection:

All interconnection breakers are interlocked in PMS for protection against parallel feeding.

All interconnection breakers are operated by protection relays to isolate bus sections in case of a fault on one of the bus sections. For detailed description see documentation form HV switchboard maker.

2.4.8 230V Feeder breakers

Control

- Close command
- Open command

Monitoring

- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no local manual reset necessary
- Breaker tripped and blocked - local manual reset must be done before further operation

2.4.9 230V Incomer breakers

Control

- Close command
- Open command

Monitoring

- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no local manual reset necessary
- Breaker tripped and blocked - local manual reset must be done before further operation

Interlocks in PMS:

Incomer breaker cannot be operated if:

- Busbar is feed from other side. Incomer other side is connected together with Bustie breaker.

2.4.10 230V switchboard interconnection breakers

Control

- Close command
- Open command

Monitoring

- Closed
- Opened
- Ready for operation from IAS (combined with Remote)
- Breaker tripped - no manual reset necessary
- Breaker tripped and blocked - manual reset must be done before further operation

Interlocks in PMS:

Breaker can be operated when:

- Breaker is ready
- Not tripped and blocked

Protection:

Interconnection breakers are interlocked in PMS for protection against parallel feeding.

2.4.11 Emergency Ship Generator

The emergency switchboard is a 440 V switchboard and is fed from the No.2 and No.3 thruster auxiliary panels. In the event of a blackout on the emergency switchboard the emergency generator starts and speeds up and gets connected to the board with in 45 seconds as per rule requirement

There is no control of Emergency ship generator from PMS. PMS is monitoring the below listed statuses:

- Generator running
- Incomer to status (open/closed)

2.5 Consumer Load Control & Limitation

2.1.1. General description

Kongsberg Maritime has a particular software module developed to handle load control and power limitation. The power limitation function is implemented to prevent overloading and tripping of generators. The system will calculate a maximum allowed load for the different consumers. The following functions are included:

- Limitation of consumers load increase based on available generator capacity.
- Load reduction based on average bus load.
- Load reduction based on individual generator load.
- Load reduction based on individual generator current.
- Load reduction based on bus frequency.
- Load reduction based on Engine Trip Detection

The power limitation is based on sending a signal for maximum load (kW) to the consumer. If no such interface is available, the signal has to be converted outside this module (e.g.: conversion from load to pitch). It is also required to have a load measurement from the consumer or a calculated load value.

All consumers that exceeds their load set point will be reduced with the overload value or until their minimum value is reached. If there is more than one consumer with the same set point, their overload will be equally divided on these consumers.

To prevent overload and blackout at fast increase of generator load, the load reduction function must have a quick response. The software will be executed at 10Hz and the necessary I/O signals (generator-load and –current, bus frequency) will be read with the same speed. The software will read load conditions on other buses via a Net-IO.

Limitation of load increase

If no load reduction parameters are exceeded, the consumers can increase the load up to their defined priority. The priority defines how much (in %) of the total capacity that can be used. The priority between the different consumers can be adjusted by giving them different values.

Consumers can increase their load according to the following formula:
*DeltaP = K1 * (K2 * (own bus capacity * consumer priority(%) – own bus load)*
*+ K3 * (other bus capacity * consumer priority(%) – other bus load))*

K1 is a percentage weight between the consumers. The value will be recalculated to take into account only running consumers.
K2 and K3 indicate how much of the available power on own and other connected buses that can be used. K2 can be set to max 80% and K3 to max 50%.
In addition to the calculated maximum load, a maximum load increase per second (ramp function) can be defined for each consumer. It can also be defined a delay after power reduction before load increase is allowed.

If parameter "Reduce capacity with reserved load" is set to 1 or 2, the reserved load will be added to measured load when calculating load increase.

Load reduction based on average bus load>

Overload is detected if the load on either own bus or other buses exceeds the defined setpoint for each consumer.

Overload own bus :	*Own bus load – consumer priority(%) * own bus capacity*
Overload other bus :	*Other bus load – load reduction on other bus – consumer priority(%) * other bus capacity*

The overload for each consumer must exceed a deadband (defined in % of consumer nominal load) to cause a load reduction. Already initiated load reduction on other bus is not included in the overload calculation. The calculated load reduction on own bus is sent to the other buses via the *swbd* module.

All consumers that exceeds their load setpoint will be reduced with the overload value or until their minimum value is reached. If there is more than one consumer with the same setpoint, their overload will be equally divided on these consumers.
Each consumer that is reduced will initiate a alarm.

If parameter "Reduce capacity with reserved load" is set to 2, the reserved load will be added to measured load when calculating load reduction.

Load reduction based on individual generator load and current.

A maximum value for generator load (in % of nominal load) is defined (typically 105-115%). The nominal load will be received from the *swbd* module and is reduced if the engine is in a start up phase with load limitation or in a slowdown mode.

A maximum value for generator current (in % of nominal current) is defined (typically 110-115%) Based on the current measurement, an overload value (kW) is calculated according to the following formula:

$\Delta P = \Delta I * U * \sqrt{3} * \cos\Phi$

where ΔP = overload

ΔI = overcurrent

U = bus voltage

The highest value of overload based on either generator load or current is used for load reduction.

If one or more generators exceed a limit, the consumers will be reduced. The calculated generator overload is set on a terminal and should be hard wired to the other PMS nodes to assure a quick response. The module will read overload signals from all connected buses.

The load reduction will be done in one of the following alternative ways:

- All consumers will be reduced with the sum of the overload on all connected buses. This gives a "unnecessary" high reduction, but it will be a quick response and a high degree of security.
- All consumers will be reduced so that total reduction is the sum of the overload on all connected buses multiplied with a predefined factor.
- All consumers will be reduced so that total reduction is the sum of the overload on all connected buses multiplied with a predefined factor. The overload signal sent to other buses will be reduced with the load reduction on own consumers.

If the load reduction is active in a predefined time and a generator is still exceeding the overload limit, an alarm is generated.

Load reduction based on bus frequency

A minimum value for bus frequency (in Hz) is defined. If the frequency is below this limit, all consumers will be reduced. This function is based on frequency on own bus and is independent of other buses. The difference between the measured frequency and the limit will be input to a PI regulator that will generate the load reduction.

Load reduction based on Engine Trip Detected.

The system will do a predefined cut off power if the spare cap is under the size of one engine nominal power, prior to the Trip. The power cut off function is a linear cut off according to how many engines that's online when trip is detected.

2.5.1 K-Pos Blackout Prevention

The K-Pos/K-Thrust system will limit the thruster speed orders in case the load on the corresponding bus section exceeds 95 %. This function is using the status of all the switchboard tie breakers and generator power readings to determine power available for each thruster. Note that due to the nature of the K-Pos system, this function will not be able to handle very quick load variations. This system will work in both the dynamic position mode as well as the manual thruster control mode (joystick control). An event alarm on the K-Pos/K-Thrust system will be given when the load limitation has been activated.

2.5.2 Power Limit Integration between K-Pos and K-Chief

The K-Pos and the K-Chief are integrated with communication on the networks. K-Chief will all the time inform the DP system about how much power each generator are loaded with, so the DP always know the load and can calculate the K-Pos internal blackout prevention. K-Chief also send info about reserved load, that means if anything special going on with the generators or switchboards it will inform DP about that, by retract kW from the normal maximum load on the engines by using load reserved. For example if a generator is in manual mode, then only the load that the generator takes at that moment will be the maximum for that generator. The DP system will then calculate and use the correct amount of power in all different types of situations according to what's going on in the K-Chief system and the power plant in general.

When a thruster is set to manual lever control (individual for each thruster), the K-Pos blackout prevention system is not in operation for this thruster(s). To be able to have a quick time response on manual lever control, this function is omitted. The PMS Blackout Prevention will be operative in manual mode.

2.5.3 Power Limiting – Thruster Drives

There are 3 signals to/from each standalone phase back system thruster VFD:

- Power Limit – Hardwired AO from PMS to thruster VFD
- Power Consumed – Hardwired AI use the direct measurement directly from the Thrusters from VFD
- Power Limitation Active – Serial (Profibus) IO from VFD to PMS

The signals are connected to the thruster FS. The interface to PMS FS's is via high speed Net-IO.

The communication between the different PMS nodes regarding power situation on other buses will be dependant of transfer breaker status. If two switchboards are connected together the necessary information will be exchanged between the dedicated PMS nodes on the network.

2.5.4 Power Limiting – Drilling

PMS has no direct control over the topside drives, but PMS will provide one "Power Available" signal to the drilling control system, from Port, Cent & Stbd main switchboards respectively, that indicate the allowed power (MW) for drilling use.

This interface consists of 1 signal group per switchboard room (Port, Centre, Stbd), with a total 3 signals.

These interfaces consist of 3 signals each, all communicated via the redundant DCS-PMS Profibus DP serial link:

- Power available– (AO) from PMS to DCS
- Power Consumed –(AI) from DCS to PMS
- Power Limitation Active –(DI) from DCS to PMS

Note. When detecting a Profibus link communication failure, a stand-by generator will be started.

Additionally the ABB standalone phase back system drilling is sending the following signal:

- Power Limitation Active – Hardwired (DI) from ABB drilling drive to PMS

Power available signal from PMS to drilling control system indicates the allowed power (kW) for drilling use:

4 mA = 0 % (No power available for drilling)

20 mA = 100% (8000 kW available for drilling)

The Drill Control System, based on this signal or signals, shall take action to reduce or increase the drill loads.

An alarm should be given in the drilling control system in case the power available signal is out of range.

When any of the drilling machinery has an actual speed setting that is less than the operator speed setting, the “Power limitation active port, centre or starboard” signal is activated. The PMS will generate an alarm based on this input.

Information exchange between PMS nodes regarding backup signal will be High Speed Net IO.

The communication between the different PMS nodes regarding power situation on other buses will be dependant of transfer breaker status. If two switchboards are connected together the necessary information will be exchanged between the dedicated PMS nodes on the network.

The PMS stations will calculate the available power on each bus section (rated power on connected generators minus delivered power from the generators). The available power for drilling is 60% of remaining available power on net + consumed power of drilling equipment.

The power available signal to the DCS will however be limited so that the drilling plant can take only 60% of the present available power on the net additionally. This is done to prevent a sudden jump in drilling power consumption that in the event that other consumers increase load at the same time, can lead to an overload of the power plant.

2.5.4.1 Drilling operation modes

Drilling operation will be consisting of four different modes:

1. Normal drilling operation
2. AHC -Active Heave Control mode on
3. AHC –Active Heave Control locked to bottom
4. Heavy weight handling

The different modes will be sent from drilling to PMS, and the PMS will confirm that the selected mode is received back to DCS.

If one of this mode is selected, the PMS will force the minimum amount of running generator to 2.

The PMS consumer load control will base the prioritizing according to the following table.

For different modes, NOV will send different values of Minimum Reserved Power to PMS. There are 3 Minimum Reserved Power for each DC Bus and correspond to relative HV switchboards.

Prioritizing:

No	Description	Min Load kW	Nom Load kW	Max incr. kW/s	Consumer Prioritizing %	Part of incr. %
1	Drilling	Min Req.by NOV	5400	4500	93	20
2	Thruster 1	200	5500	5500	100	20
3	Thruster 2	200	5500	5500	98	10
4	Thruster 3	200	5500	5500	98	10
5	Thruster 4	200	5500	5500	98	10
6	Thruster 5	200	5500	5500	98	10
7	Thruster 6	200	5500	5500	100	20

Minimum Power:

- **Consumer is not activated, minimum power will based on the setting according to the table above**
- **Consumer is activated, minimum power will be the maximum values between Minimum Power Setting and Max Increase pre- scan (100ms). If the available power is lower than Max Increase Pre-Scan, the minimum power will be set to the value according to the table above.**

2.5.4.2 Drilling Switchboard Configuration Cases

PMS is calculating Power Available based upon switchboard configuration. The DC bus is unknown for PMS. For this reason the power available signal has to be treated accordingly. The following chapters describe the different cases.

2.5.4.2.1 Case 1

11 kV switchboards disconnected and DC bus opened. All drilling feeders are closed.

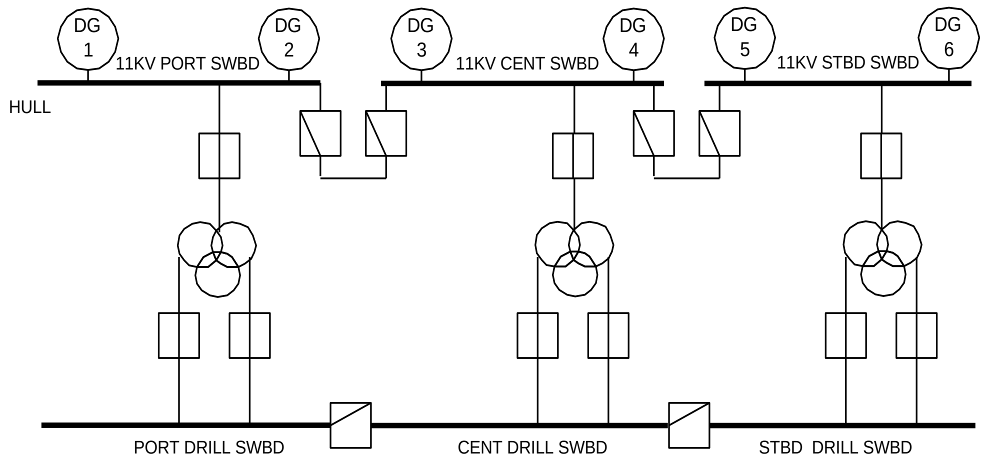


Figure 2-7 Case 1

PMS is calculating power available as for three independent switchboards. These signals are used by DCS separately for the three DC buses.

2.5.4.2.2 Case 2

11 kV switchboards connected and DC bus opened. All drilling feeders are closed.

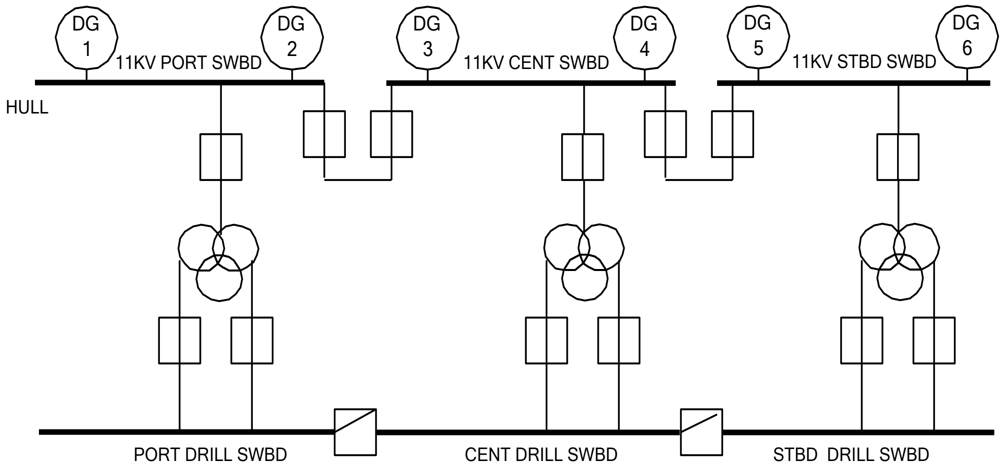


Figure 2-8 Case 4

PMS is calculating power available as for three interconnected switchboards. These signals are used by DCS separately for the three DC buses.

2.5.4.2.3 Case 3

11 kV switchboards connected and DC bus closed. Only one drilling feeder is closed.

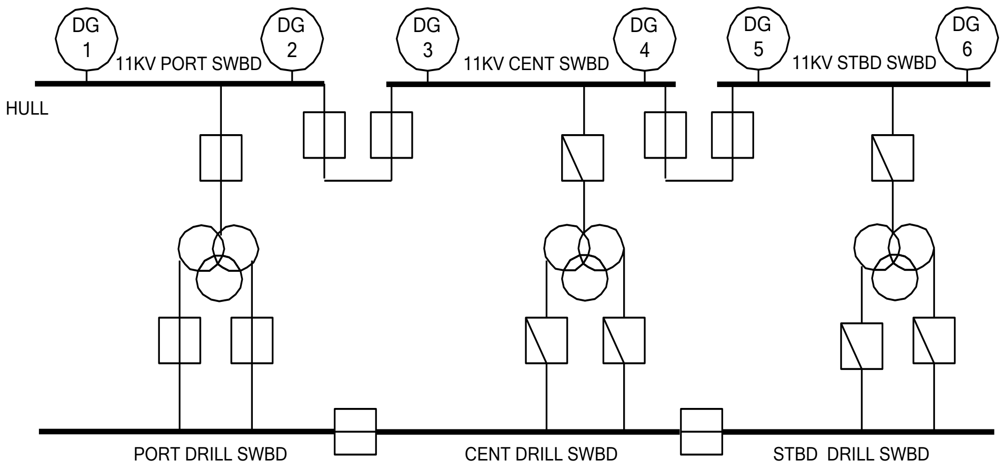


Figure 2-9 Case 5

In this case DCS shall use power available for the connected side for all consumers on the interconnected DC bus.

2.5.5 Blackout Prevention Summary

There are two large groups of electric power system consumers on this vessel, the thruster system and the drilling drive system. Both of these large groups of consumers are controlled by variable frequency AC drives. Both of these systems require load limitation functions with respect to increase rate control and load limitation in order not to overload the power system when increasing the load. Also the loads of such consumers must be reduced in case other consumers of the vessel increase load, or in the event of loss of a generator. Because this is a dynamic positioned vessel the thruster drives will always take precedence over the drilling drives control system. There will be an order of precedence for operation of the drilling drives.

BLACKOUT PREVENTION

POWER AVAILABLE VERSUS POWER USED PMS

PMS compares, each scan time ~100 ms, the connected power with the power used and sends "kW Available" signals to "Drilling" and "Thrusters".

If any load exceeds its **KW Available** signal, PMS raises this alarm. **Time = 100 ms**

Thruster: **ABB Thrusters VFD will respond to KM power limit signal and will phase back the thrusters, following KM power available (limit) signal (4-20mA) until the overload is rectified.**
Time=50ms

Drilling: **NOV will respond to KM power limit signal and will reduce in the following order, until the overload is rectified.**

Time = 75 ms

DP: **KM DP will limit the thruster speed orders, if the system load is over 95% of available nominal Power minus Reserved load from PMS.**
Time = 1-2 sec

FREQUENCY
/ Internally
from 11kV
Switchboard

Step 1: **If the frequency drops below 58Hz, KM VC will reduce the power available (limit) signal.**
This is done by using a PI-controller.
When the frequency recovers to 59.5 Hz, the power available will be increased if required.

Step 2 **ABB Thruster VFD from a frequency input will independantly reduce power if frequency drops to 57Hz**
for 100 ms. If frequency continues to drop, ABB will reduce power accordingly in a linear function.
At 54Hz power will be reduced to 0%
After frequency is restored to 58Hz for 2 sec, ABB will release power back to normal function.

ABB Drilling VFD will limit power instantly to 75% of current load if frequency drop below 57Hz.
From 56Hz, limitation will be proportaional to net frequency reching full reduction (minimum power limit value,
600kW each VFD) at 54Hz as alinear funcrtion. A deadband is present between 56-57Hz.
The Frequency routine will deactivate after frequency has been above 57Hz for over 30 sec.
ABB Thruster drive and Drilling VFD have an event based fasr load reduction system additionally

	of whitch reaction time is below 50ms. **In the event of load reduction, it will dependently reduce the thruster drive loads by using the internal algoithm.** **Drawworks, Mud pump, Top and Cement Drive are not limited unless necessary for achieving necerssary load reducrion.**
	Step 3: **In case the 11 KV swbd's are closed KM VC will split the 11 KV swbd's into three, (i.e. bus tie breakers between boards 1, 2 and 3 will open), should the frequency drop below 54 Hz for 3 sec or above 66 Hz for 3 sec. The next standby generator set will be** **started after 11KV bus split, should the frequency remain below 57 Hz.**

Table Table 2.5-1 BLACKOUT PREVENTION

Note: (*) Consumer Prioritizing (%) is based on 4 Drilling Modes. See table in 2.5.4.1 Drilling operation modes.

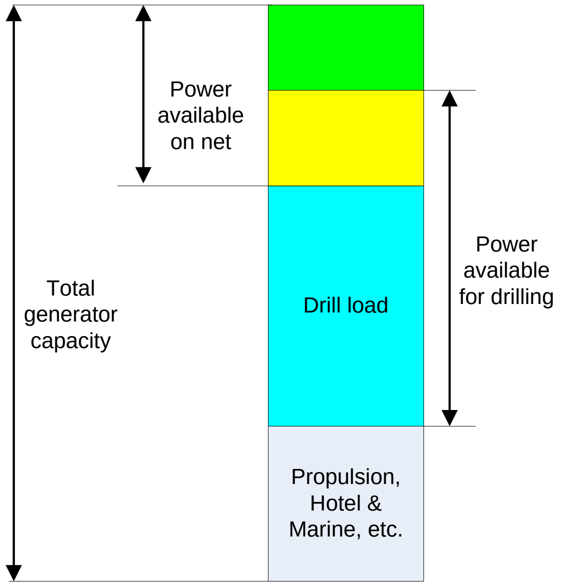


Figure 2-10 Power available calculations

The scan rate of these calculations will be 10 Hz. Also the “MGE Load” signals between the PMS stations (used for calculation of available power to drilling) will be performed at the same scan rate.

In the event that one or more generators are overloaded, the power available signal will be reduced accordingly (power available for drilling = drill load - ∑ generator overload).

All the drill plants (port / cent / stbd) will receive a reduction requirement that equals the total generator overload, provided that port, centre and starboard bus sections are interconnected.

If the power consumption on the drilling equipment is higher than the available, the DCS will reduce the operating drilling equipment speed until the power consumption is within acceptable limits.

The DCS will first reduce dynamically topside drive and mud pump at the same time, then the draw work will be reduced to a minimum 500 kW.

2.5.6 K-Chief blackout prevention

The K-Chief Power Management System is monitoring the load and frequency on each busbar as well as the load on each individual Main Generator Engine. As backup for the K-Pos / K-Thrust blackout prevention, the following functions are implemented in the K-Chief Power Management System:

- In case of the load on any MGE exceeds 105%, the power available signal to the thruster which is feed by the corresponding MGE, will be automatically reduced. All consumers will be reduced with the sum of the overload on all connected buses.
- In case of current on any MGE exceeds 110%, the power available signal to the thruster which is feed by the corresponding MGE, will be automatically reduced. All consumers will be reduced with the sum of the overload on all connected buses.

- In case of the load on any switchboard exceeds 100%, the power available signal to the thruster which is feed by the corresponding switchboard, will be automatically reduced. All consumers will be reduced with the sum of the overload on all connected buses.
- In case of the low frequency (less than 58Hz) on any switchboard, the power available signal to the thruster which is feed by the corresponding switchboard will be automatically reduced. The first standby Generator will start on that switchboard by PMS. All consumers will be reduced with the sum of the overload on all connected buses.
- In case of frequency drops below 54Hz, the bus tie will be tripped and split to 3-spilt mode after 3 seconds, and if the frequency is still below 57Hz after 1 second, then the PMS will immediately add one generator to the particular switchboard.
- In any case of automatically reduction of the power available performed by the PMS, an event message will be routed to the K-POS/K-THRUST system.
- In case of frequency is above 66Hz, the bus tie will be tripped and split to 3-spilt mode after 3 seconds,

The figure below shows an example of the power available (limit) signal to the thruster. The basis of this scenario is: start of the thruster, a generator trip, and a standby start – connect of a new generator.

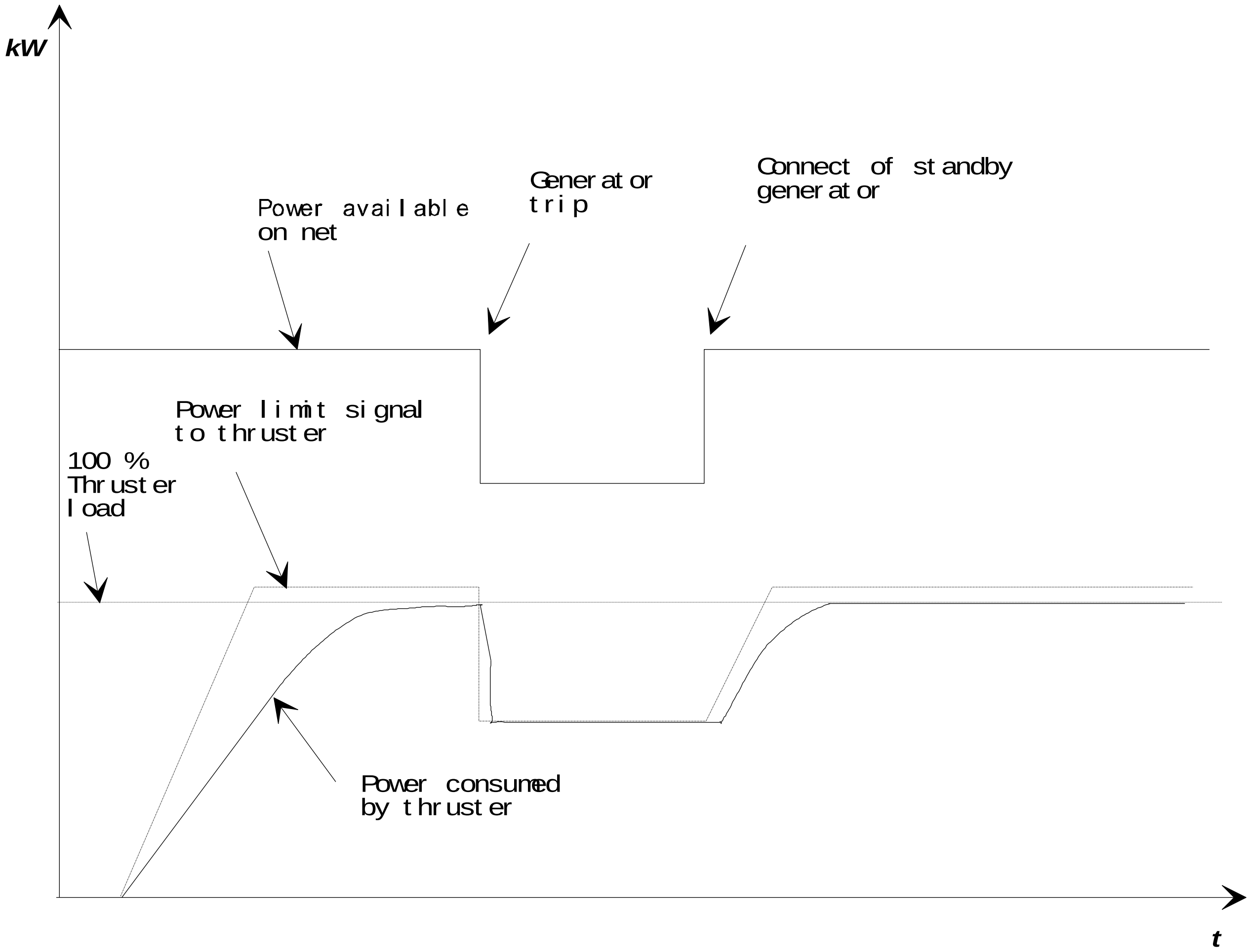


Figure 2-11 PMS blackout prevention power limit signal

2.5.7 Drilling Drives Rate Increase Control

There is no automatic load increase rate control of the drilling plant implemented in KM PMS.

2.5.8 Thruster Drives Rate Increase Control

One ACS-6000 frequency converter is dedicated to each thruster to maintain the RPM control necessary to accelerate/decelerate the drive to the reference value. The power available (limit) signal to each thruster will include a ramp function. Based on the load up parameters for the engines and number of generators connected, the power available (limit) signal will be ramped up according to these parameters. Ramp time for the diesel engine is 0 – 100 % load in 20 seconds. The thruster ramp time for the power limit will be based according to the generators load curve.

2.5.9 Power re-generation protection

No re-generation is applied for this vessel; the drawwork will burn off the regenerated power on load banks.

2.5.10 Drilling Spinning Reserve

To ensure that there is always enough power for special drilling operation requirements, the PMS will reserve additional power as follows:

The “power reserve” is added to the actual power consumption prior to load dependent start / stop calculations.

The amount of power reserved is received from NOV via Profibus, “minimum Reserve Power”. 3 “minimum Reserve Power” (Port/Centre/Stbd) will be added together and distribute to 6 HV switchboards equally.

2.5.11 Load shedding systems

On the 11kV there is no load shedding system in PMS for tripping of consumers in case of generator overload.

Note: There is a load shedding function in the 440V SWBDs and FWD 230V SWBD, performed by SWBD itself by detecting over current at incoming breaker. “Preferential trip” signals are connected between each SWBD and IAS

2.5.12 Minimum Generator Online

	DP Mode	Normal Drilling	Drilling Mode 2-4
Close Ring	2	1	2
Open Ring	2	1	2
2-Split Mode	2	1	2
3,4,5,6-Split Mode	1	1	1

2.6 Advanced Generator Supervisor (AGS)

The Advanced Generator Supervisor (AGS) System integrated in the Power Management System in Kongsberg Maritime Integrated Automation System (IAS). Functions within other systems are not described in this document.

2.6.1 AGS System Layout

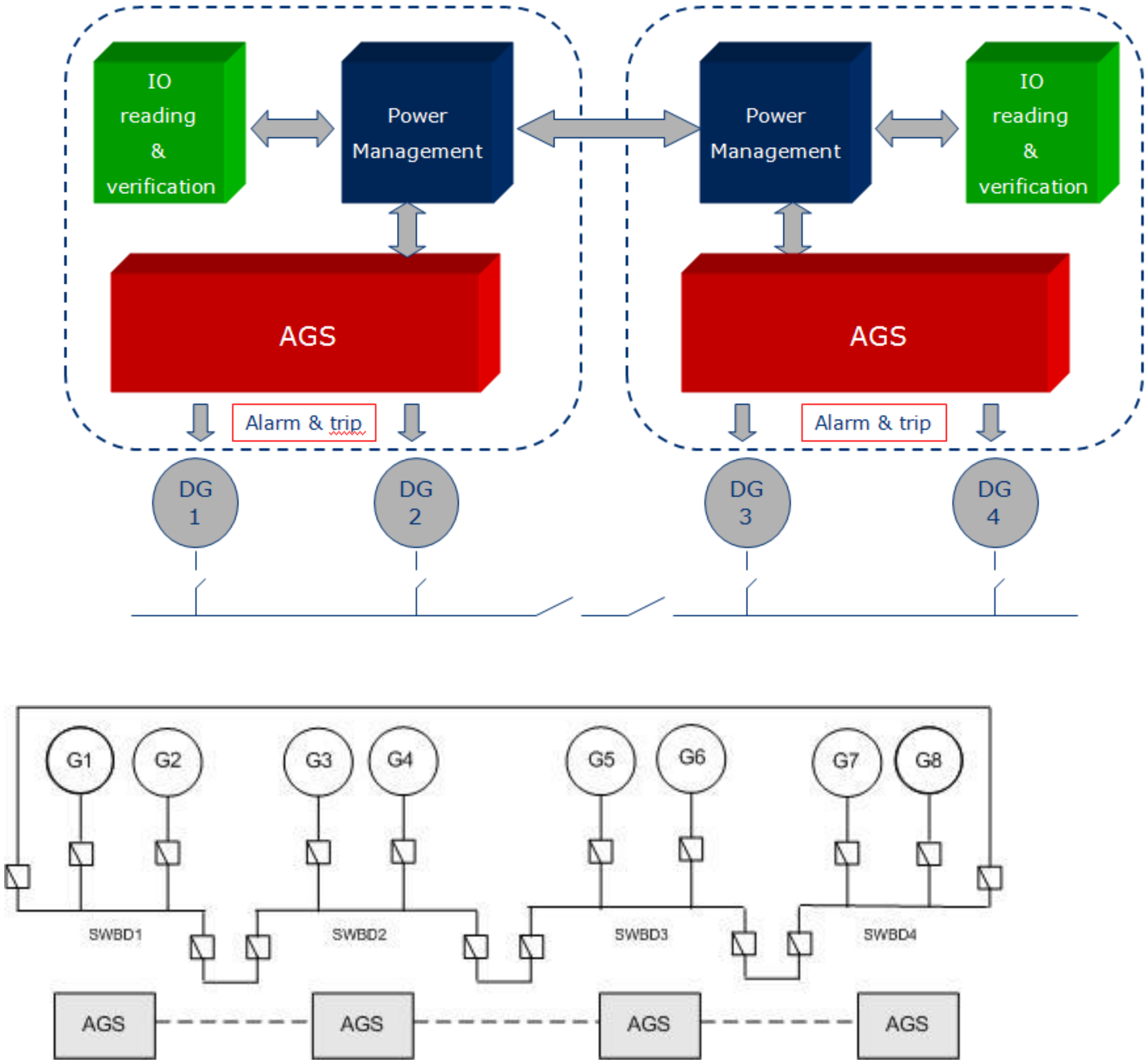


Figure 1 AGS Layout

2.6.2 AGS Function

For this project, AGS function is integrated in PMS. Operator also has an option to turn “ON” and “OFF” the AGS function from PMS mimic page.

The AGS consist of two main functions:
Monitoring of speed control system (active load sharing).
Monitoring of voltage control system (reactive load sharing).

AGS will continuously compare measured values with expected values calculated from an internal model of the system to detect which engine has a fault condition.

Each switchboard segment is equipped with its own AGS function, but reviews overall power plant status and other AGS status from the different connected switchboard nodes.

AGS will work with speed control in both droop and isochronous mode of operation and adjust the internal model accordingly. The system will also handle the different asymmetric load sharing modes available. This includes asymmetric loading (base load / MW control) when the load sharing is controlled by an external system in isochronous mode.

AGS will give an alarm and can initiate a standby start if the response is not according to the internal model. If the deviation between the internal model and the response exceeds further, the AGS system will trip the faulty generator.
Some error conditions can also cause tie-breaker trip, especially if there is a very low total net load.

Fig 2 AGS Structure shows the basic structure for AGS for handling up to 4 generator sets on one switchboard. It will however be updated with measurements and conditions from all connected switchboards and see this as one net.

When AGS in “ON”, both alarms and trip function are activated.
When AGS in “OFF”, no trip function, but alarms will still be raised up in the system to warn the operators.

When AGS in “ON” and one fault generator trips, all standby generators will start (even in split bus).

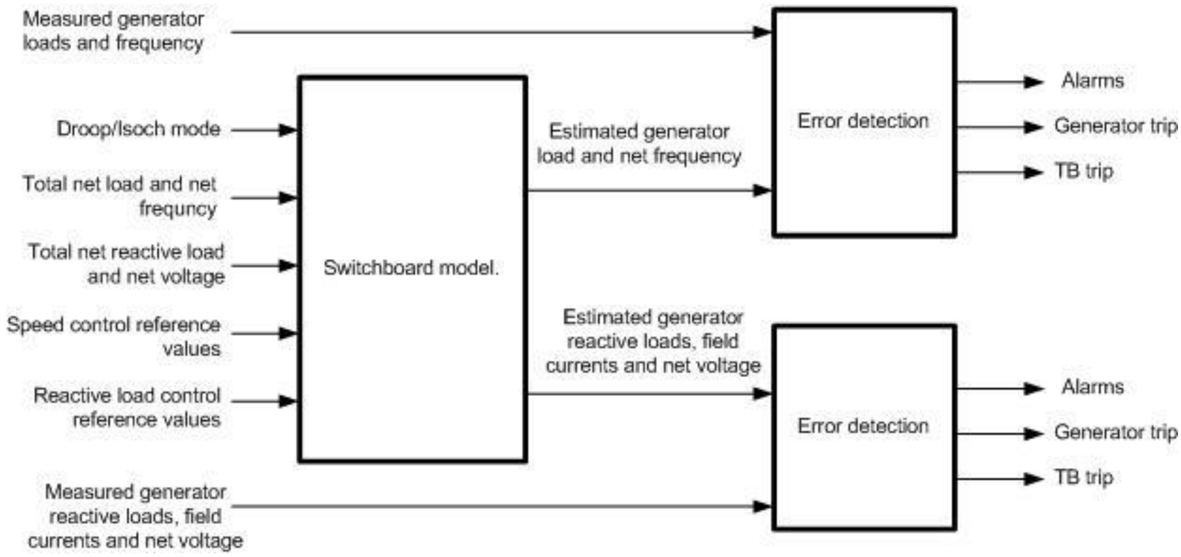


Figure 2 AGS Structure

2.6.3 Monitoring speed control system

Failure analyze on active load and frequency (failures on speed regulator / governor). AGS will continuously compare the internal load sharing set points and estimated values from the internal model with actual measurements from the system.

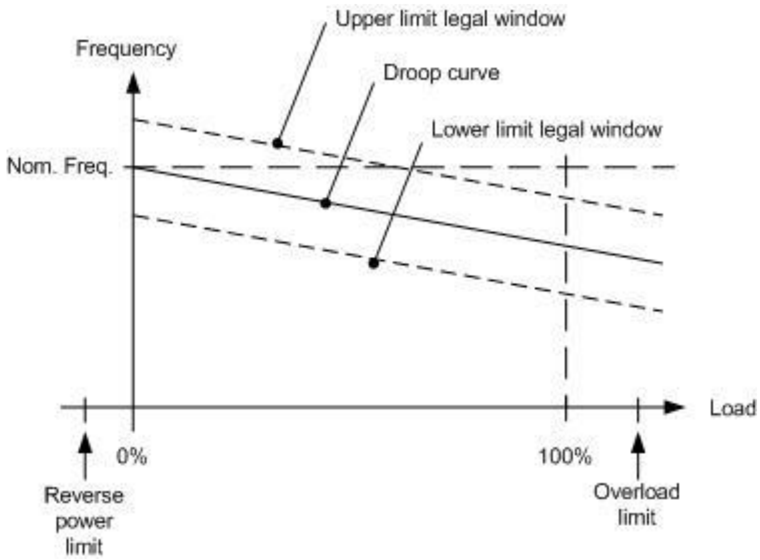


Figure 3 Speed curve

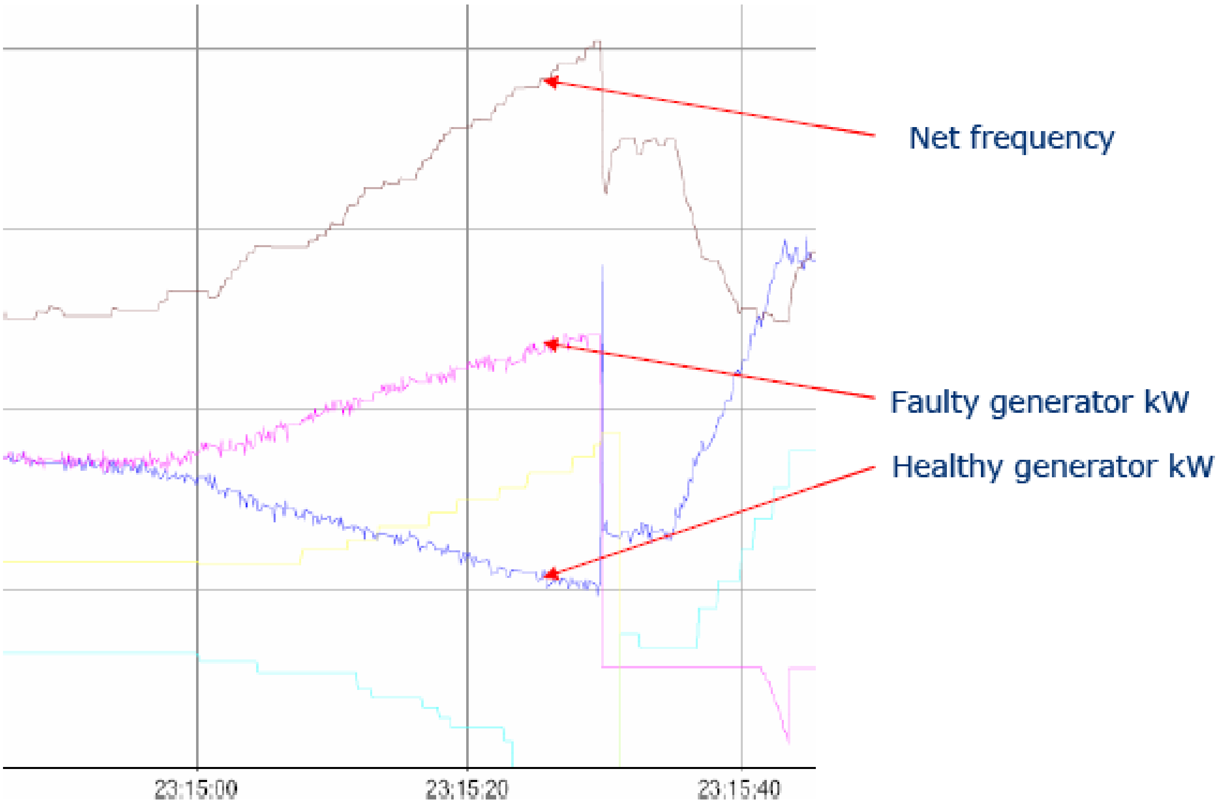
2.6.3.1 Actions by AGS on Typical Failures on active load sharing system

	Type of Fault	Result	Other Info	Alarm	Gen Trip	TB Trip	Stby Start	Switch to Droop
1	Generator not developing required load. Governor failure, clogged fuel filter, fuel quality, errors in PMS control signals or errors in prime mover. Actuator or fuel rack stuck or faulty	Low frequency and low kW. Other generators will get low frequency and high kW	First deviation level	X				
			Second deviation level		X		X	Toggle to droop if isoch
2	Generator developing too much power. Governor failure, governor feedback failure or errors in PMS control signals. Actuator or fuel rack stuck or faulty	High frequency and high kW. Other generators will get high frequency and low kW	First deviation level	X				
			Second deviation level		X		X	Toggle to droop if isoch
3	Another generator with fault 2	High frequency and low (negative) kW. Frequency is not checked if total load is low, or be always turned off. Only check negative kW	First deviation level	X				
			Second deviation level					Toggle to droop if isoch
4	Another generator with fault 1	Low frequency and high (>100%) kW. Frequency check can also be always turned off. Only check kW	First deviation level	X				
			Second deviation level					Toggle to droop if isoch
5	Net overload, load reduction failure	Low net frequency				X *)		

*) Tie breaker trip will only be performed against switchboard segments with connected generators.

Note: All standby DG will start when one fault generator trips.

Typical trend for how a speed failure will look like in failure analyze on active load and frequency:



Failure analyze on active load and fuel rack (failures on speed regulator / governor).

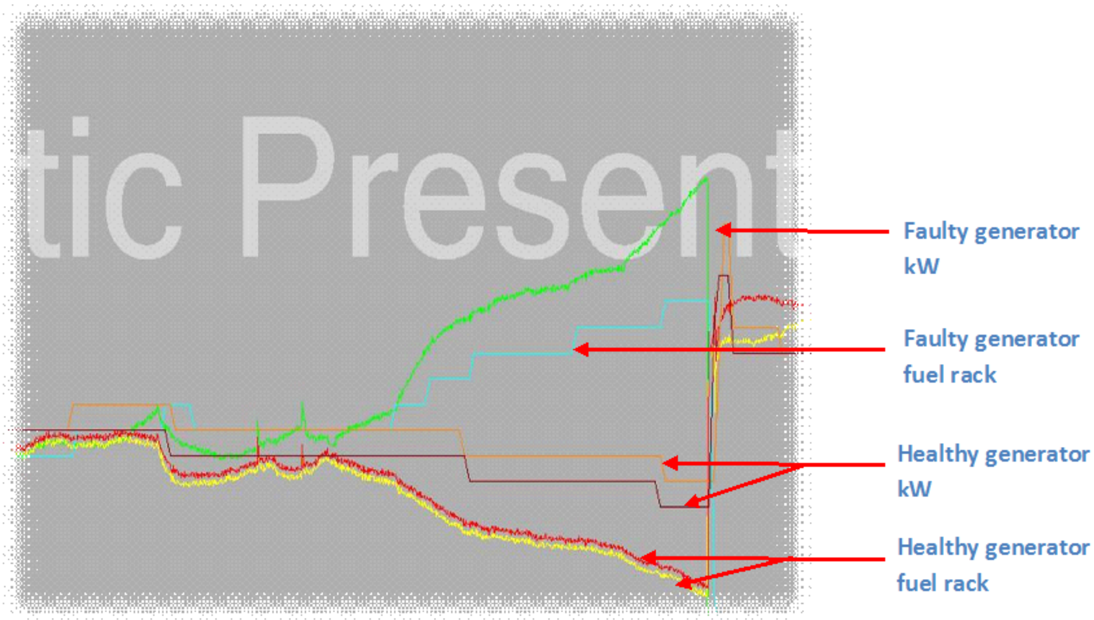
To handle situations where the net frequency changes very little when an error occurs (e.g. in isochronous mode and/or many generators connected), a voting system to detect deviations in kW and fuel rack position is added. This can be activated from parameter page and will only be in operation when there are 3 or more generators connected and controlled by load sharing system. The voting system will be active in addition to the normal check of deviation from estimated values on kW and net frequency.

2.6.3.2 Actions by AGS voting system on Typical Failures on active load sharing system:

	Type of Fault	Result	Other Info	Alarm	Gen Trip	TB Trip	Stby Start	Switch to Droop
1	Generator not developing required load.	Low fuel rack position and low kW.	First deviation level	X				
		Other generators will get high fuel rack position and high kW	Second deviation level		X		X	Toggle to droop if isoch
2	Generator developing too much power.	High fuel rack position and high kW.	First deviation level	X				
		Other generators will get low fuel rack position and low kW	Second deviation level		X		X	Toggle to droop if isoch

Note: All standby DG will start when one fault generator trips.

Below is an example for one faulty generator and two healthy generators where the voting will detect deviation even though the net frequency change is very little:


Faulty generator kW
Faulty generator fuel rack
Healthy generator kW
Healthy generator fuel rack

2.6.4 Monitoring voltage control system

Failure analyze on AVR (failures in AVR, net voltage, KVAr and generator field current).

AGS will all the time compare the internal load sharing set points and estimated values from the internal model with actual measurements from the system.

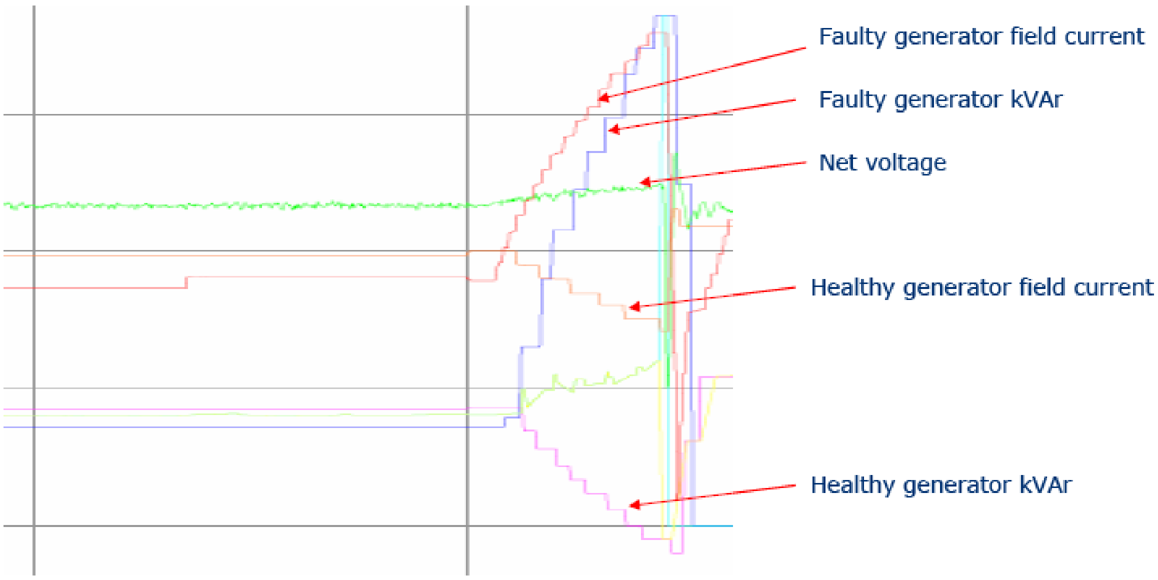
2.6.4.1 Actions taken by AGS based on Typical Failures on AVR (Voltage control system):

	Type of Fault	Result	Other Info	Alarm	Gen Trip	TB Trip	Stby start	Switch To Droop
1	Over-excitation, loss of voltage feedback to AVR	Voltage, field current and kVAr high	First deviation level	X				
			Second deviation level		X		X	Toggle to droop if isoch
2	Under-excitation, AVR fault	Voltage, field current and kVAr low	First deviation level	X				
			Second deviation level		X		X	Toggle to droop if isoch
3	Another generator with over-excitation.	High voltage, low or reverse kVAr. Voltage is not checked if total load is low or check can also be always turned off. Only check kVAr	First deviation level	X				Toggle to droop if isoch
4	Another generator with under-excitation.	Low voltage, high (>100%) kVAr. Voltage check can also be always turned off. Only check kVAr	First deviation level	X				Toggle to droop if isoch
5	High reactive load on the system	Low voltage and high kVAr and generator current Voltage check can also be always turned off. Only check kVAr	PMS Consumer Load control will do quick reduction based on high generator current. If still low voltage, then system will trip bus-tie breaker	X				Toggle to droop if isoch

Note: All standby DG will start when one fault generator trips.

*) Tie breaker trip will only be performed against switchboard segments with connected generators.

Typical trend for how an AVR failure will look like:



Failure analyze on AVR (KVAr and generator field current).

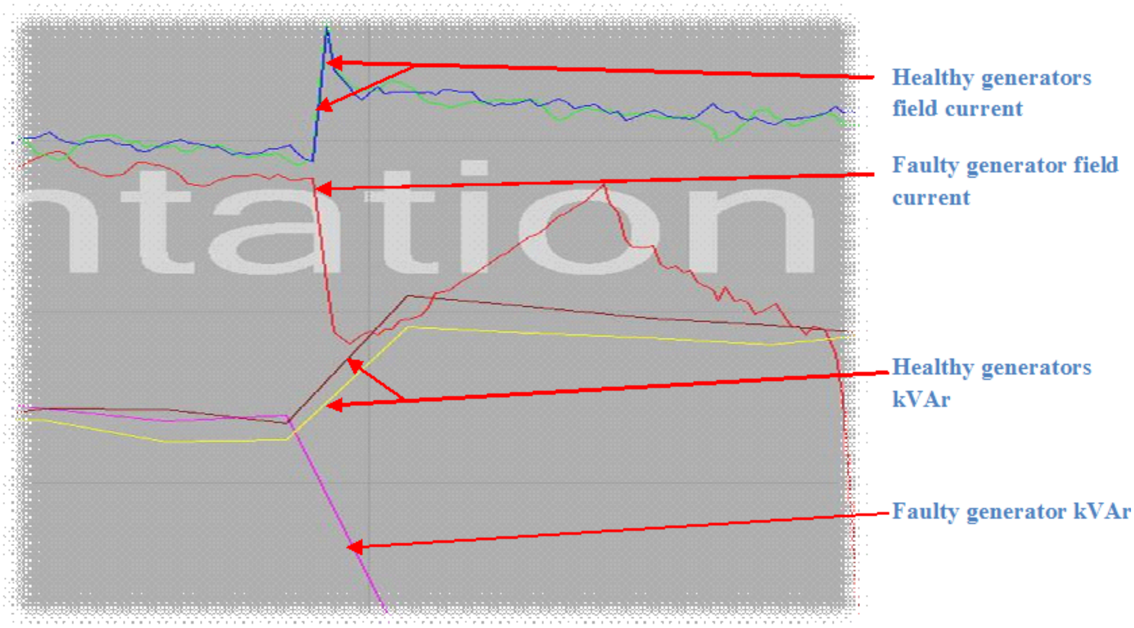
To handle situations where the net voltage changes very little when an error occurs (e.g. when many generators connected), a voting system to detect deviations in kVAr and field current is added. This can be activated from parameter page and will only be in operation when there are 3 or more generators connected. The voting system will be active in addition to the normal check of deviation from estimated values on kVAr, field current and net voltage.

2.6.4.2 Actions by AGS voting system on AVR-Voltage control system

	Type of Fault	Result	Other Info	Alarm	Gen Trip	TB Trip	Stby start	Switch To Droop
1	Over-excitation,	Field current and kVAr high	First deviation level	X				
		Other generators will get low field current and low kVAr	Second deviation level		X		X	Toggle to droop if isoch
2	Under-excitation,	Field current and kVAr low	First deviation level	X				
		Other generators will get high field current and high kVAr	Second deviation level		X		X	Toggle to droop if isoch

Note: All standby DG will start when one fault generator trips.

Below is an example for one faulty generator and two healthy generators where the voting will detect deviation even though the net voltage change is very little:



2.6.5 Isochronous Load Sharing Command Monitoring

AGS has a function to monitor the isochronous load sharing. There is a 4-20mA input load sharing command signal from each governor to monitor the isochronous load sharing, and signals will be converted to 0-100%. These signals must be linear with each generator wanted load.

In Isochronous mode load sharing, AGS will continually measure these input signals from each governor and do the comparison with estimated values based on model calculation. If there is a failure in isochronous load sharing line like short circuit/open circuit, AGS will detect this failure and switch the power plant to droop mode. Based on the recommendation from Doosan/Woodward, the settings are set to 5% deviation with 1s delay. But these parameters can be changed with higher user access under parameter page of AGS module.

2.6.6 Bus-tie Trip Function

If the frequency on the switchboard, continue to go further down, even after KM has tripped the faulty generator, the Low frequency trip function in AGS will split the switchboards on a certain low frequency set point by tripping selected Bus-ties.

2.6.7 AGS Interface

To be able to do the analyses, the system needs a set of measurements values and status signals. To get the required speed in the failure check algorithms, all transducers and calculations must have an update rate of 10Hz or faster since KM IO will be read in 10Hz.

Important signals on the PMS including AGS/HIL		
	Signal Type	IO Type
Generator breaker	DI	In Closed
	DI	In Opened
	DI	Local Remote
	DO	Open
	DO	Close
	AI	Tbflow
	AI	Power factor
Measurements Generator breaker field	AI	Current 1 (phase) Fast sensor, better than 10Hz
	AI	Current 2 (phase) Fast sensor, better than 10Hz
	AI	Current 3 (phase) Fast sensor, better than 10Hz
	AI	Voltage 1 (phase) Fast sensor, better than 10Hz
	AI	Voltage 2 (phase) Fast sensor, better than 10Hz
	AI	Voltage 3 (phase) Fast sensor, better than 10Hz
	AI	kVAr, Big enough range for spikes. Must handle reverse kVAr.
	AI	kW 1, Fast sensor, better than 10Hz

	AI	kW 2 (optional) Fast sensor, better than 10Hz
	AI	Frequency, Fast sensor, better than 10Hz
AVR	AI	Field Current (Magnetisering) The accuracy of the sensor must be good, better than 1% of the small range (0-10 A)
	DI	Alarm
Bus tie breaker	DI	In Closed
	DI	In Opened
	DO	Open
	DO	Close
	AI	Tbflow (kW true the CB)
Switch board	DI	Deadbus (also for LV)
	DI	Deadbus (second deadbus confirmed, optional)
	AI	Voltage, Big enough range to handle AVR failures, Spikes
	AI	Frequency, Fast sensor, better than 10Hz
Diesel Regulator	DO	Speed Up
	DO	Speed Down
	AI	Fuel Rack
	DO	Droop / Isochronous selection
	DI	Droop / Isochronous mode
	AI	Isochronous Load sharing command signal
	DI	Governor Minor Alarm, Isoch mode Failures, MW control failures change over to Droop Mode (Optional)
	DI	Governor Major Alarm, Trip actual Generator
Diesel Interface	DI	Local Common Shutdown
	DI	Local/Remote

	DO	Start
	DO	Stop
	AI	Engine Speed
Drives	AI	Power used up to PMS field station
	AO	Power available from PMS field station
Thruster breaker:	DI	In Closed
	DI	In Opened
	DO	Open
	DO	Close
	AI	Tbflow (kW true the CB)
Common breaker:	DI	In Closed
	DI	In Opened
	DO	Open
	DO	Close
	AI	Tbflow (kW true the CB)

2.6.8 Internal model Operational Modes

The load sharing can be run in two different modes, Isochronous and Speed Droop. Load sharing mode can be selected by means of buttons on the PMS Mimic. To avoid a mix of load sharing modes on the same switchboard there is no individual mode selector on each generator, but one selection for each switchboard. If two or more switchboards are interconnected, mode selection on one switchboard will change mode for all connected switchboards.

The PMS system will toggle the different switchboards automatically if operated in remote mode. If one switchboard is operated in isochronous mode and one in droop mode and they are connected together, the PMS will automatically set both switchboards over to droop mode.

Isochronous load sharing is from PMS's point of view considered as "external control", i.e. no speed control from PMS. When Droop Mode is selected, PMS is adjusting the speed of the engine by means of raise/lower pulses to the governor.

The AGS model and failure detection will handle all modes explained further down.

2.6.8.1 Isochronous Mode

Isochronous mode is defined as follows: "A unit with zero droop is isochronous".

A generator set operating in isochronous mode will maintain the same set frequency regardless of the load it is supplying except for momentary speed changes due to load changes, up to the full load capability of the generator set.

Isochronous load sharing will perform automatic proportional division of the total load between generator sets while maintaining a fixed frequency on the bus.

All generators in the system will maintain equal percentages of their full load capacity.

When selected to isochronous the Symap will accomplish isochronous load sharing for the active generator sets.

The Symap compares the load on its generator to the load on other generators in the system, and applies the governor to increase or decrease engine fuel to maintain the generators proportional share of the total system load.

Note: Individual feedback on generators for Isochronous / Droop mode.

The PMS monitors the load of all connected generators and will, in isochronous mode, give an alarm if the load between the connected generators deviates from a defined limit.

For selection of mode: Individual pulsed output for droop and isochronous.

The PMS system will toggle the different switchboards automatically if operated in remote mode. If one switchboard is operated in isochronous mode and one in droop mode and they are connected together, the PMS will toggle automatically both switchboards over to droop mode.

There will possible to run the generator in Asymmetric mode in isochronous mode.

2.6.8.2 Speed Droop Mode

In this mode the PMS supports a number of load sharing options:

- Symmetric load sharing
- Asymmetric load sharing
- Fixed load
- Manual load sharing

The above load-sharing functions can be selected individually for each generator. Load sharing is based on active power (kW) measurements.

For load sharing and net frequency control, speed increase / decrease signals (pulses) are sent to the speed governor. The frequency of the switchboard will be maintained at rated frequency by compensating the governor speed droop.

2.6.9 Settings

The diesel engine has normally a reaction time of 15-30 seconds from 0-100%. The AGS settings are based on a normal system where you are running with 3 to 4 engines on-line and load around 40-60 %.

Then it will be approximately 10 seconds each way to either overload or reverse power. This is the philosophy behind the settings in the AGS system. You can change the values in the AGS system based on the diesel engine reaction curve.

The settings set for this project are mentioned below:

Speed Control:

Description	Limit	Alarm Delay	Trip Delay
AGS kW Overload limit	110%		
AGS kW Overload limit delay alarm		0 sec	
AGS kW Overload limit delay Trip Bus-tie			0 sec
AGS Speed control KW dev Limit droop	8%		
AGS Speed control kW dev. Limit Isoch.	10%		
AGS Speed control fuel rack dev. Limit droop and Isoch.	5.5%		
AGS Speed control Freq dev. Limit droop.	0.7 Hz		
AGS Speed control Freq dev. Limit Isoch.	0.4 Hz		
Generator taking too high load, Alarm delay		2 sec	
Generator taking too high load, Trip delay			4 sec
Generator taking to low load, Alarm delay		2 sec	
Generator taking to low load, Trip delay			4 sec
AGS kW Reverse power limit	-11%		

Description	Limit	Alarm Delay	Trip Delay
AGS kW Reverse power alarm delay		0.0 sec	
AGS kW Reverse power trip delay			0sec
AGS Low frequency TB trip limit	-6.0Hz		
AGS Low frequency TB trip delay		3 sec	

Voltage Control:

Description	Limit	Alarm Delay	Trip Delay
AGS kVAr Overload limit	130%		
AGS KVAr Overload limit delay alarm		0 sec	
AGS KVAr Overload limit delay Trip Bus-tie			0 sec
AGS Volt. Control KVAr dev Limit	10%		
AGS Volt. Control Bus Volt dev Limit	0.2%		
AGS Volt. Control Field Current dev Limit	5%		
Generator Over Excitation (High KVAr), Alarm delay		2 sec	
Generator Over Excitation (High KVAr), Trip delay			4 sec
Generator Under Excitation (Low KVAr), Alarm delay		2 sec	
Generator Under Excitation (Low KVAr), Trip delay			4 sec
AGS Reverse KVAr power limit	-21%		
AGS Reverse KVAr power alarm delay		0 sec	
AGS Reverse KVAr power trip delay			0 sec

2.6.10 Dynamic Window

The new function inside the AGS: AGS Dynamic Window

The AGS Dynamic Window will look on all other online engines on your connected power plant and hold the tripping of engines after the normal delay time as long as the fault is not doing any damage for the total power plant. This means that we are looking on the overall total load, overall reactive load and overall bus frequency. By looking at total net condition we can now allow the AGS to run with an unhealthy engine online for a longer time, and still be sure that this will not give any trip of tie-breakers or other generators.

The AGS Dynamic Window is defined as 10% (can be set on parameter page) inside the load and reactive load zone protection limits (typical -10% -> 130%) and a low frequency limit.

When an engine with a fault is Inside the AGS Dynamic Window area AGS will let the engine continue to be online. This will give your system a much better overall AGS functionality and you can run with the AGS on all the time and only trip when you are outside the Dynamic Window and a trip condition is active.

If you have extra functions where you are toggling over from Isochronous to compensated droop, you will have longer time to do this toggling without have the AGS tripping engines on the way. As long as you are doing this toggling between modes before our AGS Dynamic Window limits, you will achieve the best from AGS all the time and also try both modes of regulation before the AGS trip an engine.

Its also important that a AGS system where you are using the Dynamic Window functionality, AGS will also send info to the DG module to handle manual mode toggling based on load sharing failure more intelligent, by alter this based on the modes from AGS.

Dynamic Window Check Limit: 10%

2.7 Blackout restart

In the event of a blackout, all outgoing feeders to thruster, drilling, and distribution transformers will trip by under voltage protection. The bus tie breakers of the 11 kV switchboards will be opened because of the under voltage trip of the breakers.

In the event that blackout on the 11kVswitchboard is detected, the PMS will immediately give start order to the

- ALL standby engines
- running not connecting engines
- Healthy generators (Generator in Manual, Fixed Mode, not Standby)
- Tripped not blocked (PMS reset)

Note: Black Out is detected with Swbd Black Out relays and *bus voltage, Frequency transducer*. (If Black Out relay is activated and bus voltage and frequency is still present. No Black Out start is performed, only alarm from Black Out relay.)

There are two blackout scenarios possible. These are:

- Total blackout
- Partial blackout

In the event of a total blackout the following breakers will be tripped by under voltage protection:

- Thruster VFD feeder breakers
- Drilling VFD feeder breakers
- Distribution transformers feeders
- HV Bustie breaker (Master & Slave)
- HV interconnection breaker
- Incomers of the 690 V switchboards
- Tie breakers of the 690 V switchboards

In the event of a partial blackout, the following breakers connected to or fed from the blacked out switchboard will be tripped by under voltage protection:

- Thruster VFD feeder breakers
- Drilling VFD feeder breakers
- Distribution transformers feeders
- Incomers of the corresponding 690 V

In the event of a blackout the following breakers will be tripped by PMS:

- Drilling VFD feeder breakers
- HV Distribution transformers feeders
- HV Bustie breaker (Master & Slave)
- HV interconnection breaker
- Generator Circuit Breakers

There is 6 seconds time delay setting on ABB circuit breakers by under voltage protection. For a rapid blackout recovery, PMS will send an “Open” Command Pulse to open the circuit breakers in order to set the under voltage protection on ABB relay.

All auxiliary motors will stop due to under voltage.

PMS will send blackout confirmed to DCS for the switchboards that are in blackout.

Generator load curve:

The engine from Doosan has three load curves that they will use. The PMS will send information to Doosan which status the PMS are in (e.g. blackout, quick load or normal standby start). Out form this information Doosan will use the corresponding load curve.

Load curve for Doosan engine 16V32/40.

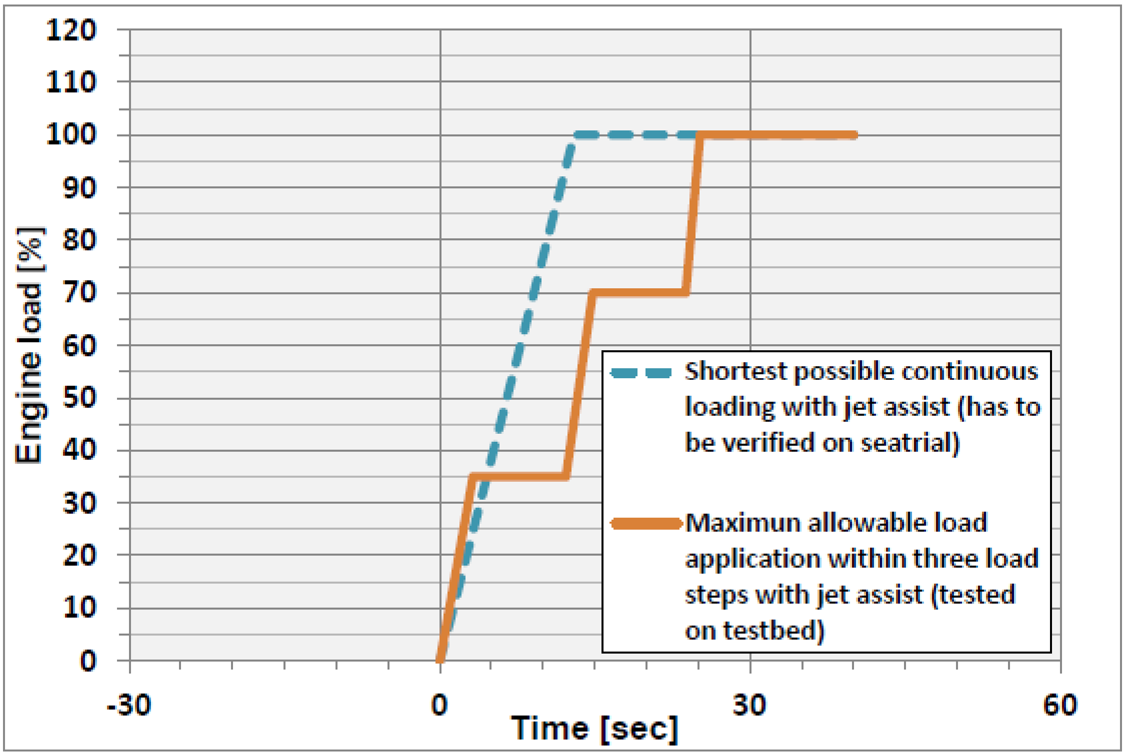


Figure 2-12 Engine load curve

2.7.1 11 kV switchboard reconnection

The PMS system will restore power after a blackout situation in a predetermined sequence. The PMS will treat each connected bus section separately and reconnect generators, transformers etc. for each switchboard. Again the position of all tie breakers is known and the configuration logic determines the sequence to be used for blackout restart.

In the event that blackout on the 11kV switchboard is detected, the PMS will immediately give start orders to all standby generator sets. The first set available (including generators already running) on each segment will be started and connected to the dead bus (synchronizing unit is bypassed).

Programmers note:

11kV bus blackout is to be detected by two conditions: bus voltage transducer and zero voltage (blackout) relay. Both conditions must be fulfilled to initiate the above function. An alarm is to be given if there is a mismatch between the two signals.

2.7.2 Reconnection of tie breakers / transformers / etc.

All bus-tie breakers will be tripped by switchboard control system, based on under-voltage detection on the 11kV bus, which divides the power system into six distinct systems. Reconnection of the bus tie section (e.g. port, centre, stbd or ring connection) breakers is a manual operation to be done after the blackout restart procedure is completed. This operation is normally remotely controlled from the PMS, but can also be done manually.

If blackout cannot be recovered in 5 min, automatically recovery function of HV breakers (Feeders, Busties) will be disabled. Operators need to close them remotely.

On ABB Switchboard, there is one function called “zone protection”. If it is activated, one H V switchboard bustie and generator circuit breaker will be TRIPPED AND BLOCKED, which needs locally reset on switchboard. And meanwhile, one alarm “Busbar Earth Fault/Short Circuit” will be trigged on PMS.

Blackout restarts HV inter connection breakers: (1A&1B, 2A&2B or 3A&3B)

After blackout the switchboard will be split in six (6). If one of the HV switchboards for some reason (e.g. start failure, not in standby) is not able to be powered. Then the PMS will automatically connect the interconnection breaker for cross feeding the HV switchboard. This will only apply for the interconnection breaker in the same engine room (e.g. port 1A&1B). Not between the switchboard port, centre, stbd or ring connection.

Signals for trigging the HV cross feeding:

- Generator start failure after first start attempt
- Generator not in standby or not available for start
- Corresponding HV switchboard have power confirmed for more than 5 seconds without the PMS have received any alarm failure
- Both switchboard have had confirmed power for more than 20 seconds

Distribution transformer feeders (units 1 for Switchboards # 2, #4 and # 6 shall be reconnected automatically provided that they were closed prior to the blackout and no interlock situation exists. The main breakers of 440 V switchboards shall be reconnected automatically when the transformers are energized provided that they were closed prior to the blackout and no interlock situation exists.

Blackout restarts LV inter connection breakers:

- After blackout the HV switchboard will be split in six (6). The LV AFT/FWD switchboards will be fed from the corresponding HV switchboard. If the LV for some reason (e.g. start failure, not in standby) is not able to be powered by the corresponding HV switchboard, the PMS will automatically connect the interconnection breaker for cross feeding the LV switchboard.
- AFT LV Distribution SWBD: There are 3 LV SWBD on AFT side. If Port/Stbd cannot be fed from corresponding HV Switchboard, cross feeding from Centre Aft SWBD. For the Centre AFT LV switchboard, it first crosses feeding from the switchboard which has fewer loads. When Port and STBD LV AFT switchboards are both power on, and Load on Port is less than Load on STBD, Centre SWBD will be cross-feeding from Port. If Load on Port is more or equal to Load on STBD, Centre SWBD will be cross-feeding from STBD. But if one of Port and STBD is Blackout, Cent SWBD will be cross-feeding from the one has power. One Distribution Transformer maximum allows feed 2 LV SWBD.
- FWD LV Distribution SWBD: There are 2 LV SWBD on FWD side. If one of them cannot be fed from corresponding HV Switchboard, cross feeding from the other.
- Drilling MCC SWBD: There are 3 LV SWBD on drilling side. If Bus A/Bus C cannot be fed from corresponding HV Switchboard, it first crosses feeding from the switchboard which has fewer loads. When Bus A and Bus C are both power on, and Load on A is less than Load on C, Bus B will be cross-feeding from A. If Load on A is more or equal to Load on C, Bus B will be cross-feeding from C. But if one of A and C is Blackout, Bus B will be cross-feeding from the one has power. One Distribution Transformer maximum allows feed 2 LV SWBD.

Signals for trigging the cross feeding:

- LV SWBD cannot be fed from corresponding Switchboard, trig cross feeding.
- There is no override function on SWBD to allow short time parallel feeding. Therefore, in order to switch back from cross feeding to normal down steam feeding, a partial blackout will happen on LV SWBD.

BlackOut Restarts of Heavy Consumers.

When detected BlockOut, a BlackOut RecoveryMode will be activated in software. This Mode will bypass the ConsumerControl function, and will ensure a quick as possible restart of Heavy Consumers.

The BlackOut Mode will be active until 20 sec after Power back.

Thruster drives shall be automatically restarted (including their auxiliary systems) provided they were in operation prior to the blackout and no interlock situation exists, following the normal start sequence.

The Drilling System transformers feeder and incomer breakers are automatically reconnected from the PMS provided they were connected prior to the blackout and no interlock situation exists.

Blackout Restarts of Thruster No.1:

Normally, Thruster No.1 should be feeder by HV Port 1A SWBD. If a blackout happens, neither Port 1A or Port 1B SWBD can be recovery in 20 seconds, Thruster No.1 will connect to HV Cent 1A SWBD which is in power. The operator need manually change it back to Port after power is restored. Thruster no. 1 feeder change-over shall be done in local side.

2.7.3 The sequence of events relating to blackout

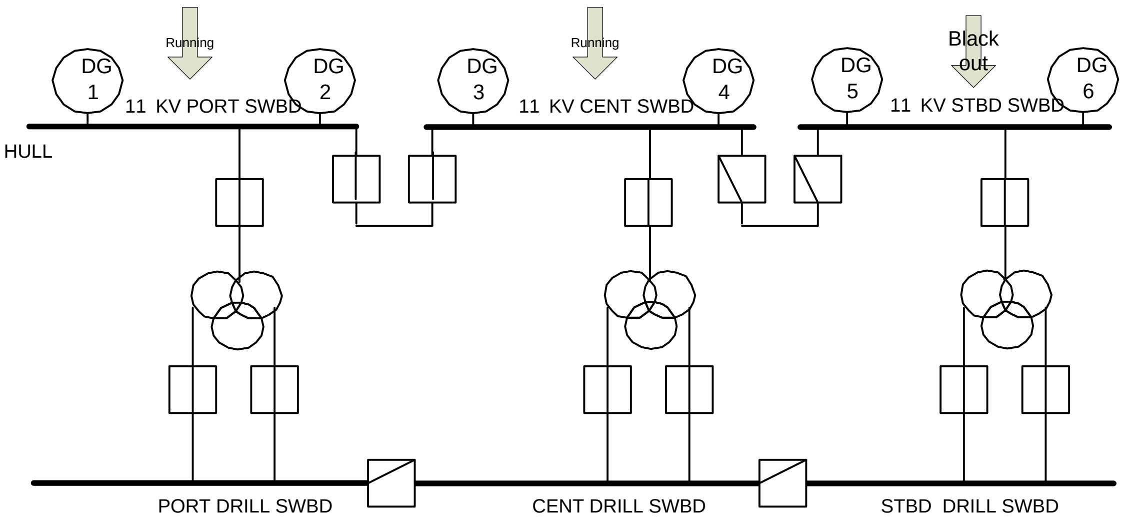
This portion of the table applies to a complete blackout in which none of the engines remain running. If only one side is blacked out, the bustie breakers are already opened and the times will apply only to the side affected.

In the event of complete blackout the switchboard will be in six split. The sequence for each switchboard will therefore be same for all six.

Sequence ID	Event	Action	Performed by
1.	1. Blackout occurs	1. On-line engines trip off line and shut down	1. Start of action

2.	2. Start all engines	2. PMS issues start command to all available engines	2. PMS
3.	3. Bus Tie opened	3. Switchboard will be split in six	3. PMS
4.	4. Transformer feeders opened	4. UVT devices open feeders for all Xfmrs	4. ABB Swbd
5.	5. Engine begins start	5. Start solenoid actuates	5. Doosan Panel
6.	6. Thruster transformer feeders opening verified	6. Thruster drives detect loss of DC Voltage and ensure feeders for thruster Xfmrs are open	6. ABB Thruster Drives
7.	7. First Main engine comes up to speed (one side)	7. Normal starting process for main engines requires about 15 seconds	7. Engine from local panel
8.	8. Breaker close order	8. Since bus is dead first engine is closed on line	8. PMS and ABB Swbd

This portion of the table applies to a complete blackout in which at least one of the engines remains running. If only one switchboard is blacked out, the bustie breakers are already opened and the times will apply only to the side affected.



Time	Event	Action	Performed by
1.	1. Blackout occurs	1. On-line engines trip off line, one swbd dead – Other swbd alive	1. Start of action
2.	2. Start engine	2. PMS issues start command to engine not running – recognizes engines already running	2. PMS
3.	3. Bus Tie opened	3. Bustie breakers between the dead swbd will opened	3. PMS

4.	4. Transformer feeders opened	4. UVT devices open feeders for all Xfmrs	4. ABB Swbd
5.	5. Engine begins start	5. Start solenoid actuates	5. Doosan Panel
6.	6. Re-close command issued to running engine	6. Since bus is dead first engine is closed on line	6. PMS and ABB Swbd
7.	7. Bus is now hot	7. Since bus is energized PMS will initiate restoration based upon tabulated values using t1 times	7. PMS and ABB Swbd
8.	8. Thruster transformer feeders opening verified	8. Thruster drives detect loss of DC Voltage and ensure feeders for thruster Xfmrs open	8. ABB Thruster Drives
9.	9. First Main engine to start comes up to speed (one side)	9. Normal starting process for main engines requires about 15 seconds	9. Engine from local panel
10.	10.Breaker close order	10. Since bus is dead first engine is closed on line	10. PMS and ABB Swbd

The following are additional times beginning with the bus becoming live, which is t=15.5 from the total blackout sequence above. If the engine remained running this time for bus live is 3 seconds. Each six swbd operates independently. Therefore the sequence will go simultaneously in parallel for each swbd.

Time	Event	Action	Performed by
1.	1. Main Bus becomes live	1. At the appropriate step above the breaker is closed and the automated load recovery starts	1. PMS and ABB Swbd
2.	2. Feeder to Drilling transformer closed	2. Drilling system power will be restored	2. PMS
3.	3. Drilling system activated	3. After power is restored to drilling equipment, driller can restart those services he deems necessary, based upon situation	3. Driller
4.	4. Feeder breaker closed		4. PMS
5.	5. 440 VAC Main Distribution energized		5. PMS
6.	6. Feeders to Engine Room MCC's closed immediately		6. PMS
7.	7. Feeder to Ships service MCC closed		7. PMS
8.	8. Power available to restart Engine Room		8. PMS
9.			9. PMS

10.	auxiliaries & fans 9. Fans and essential auxiliaries started within 5 seconds 10. Power available to feed MCC's – breakers in Dist. & MCC's begin closing after 1 second 11. Engine FW Pumps started 12. FW circulation through engine room heat exchangers initiated to begin transferring heat being circulated by engine driven pump 13. Aft FW and SW pumps started 14. Balance of water cooling system back into service aft 15. Fwd FW and SW pumps started 16. Balance of water cooling system back into service forward		10.PMS
11.	17. Thruster and Steering Drives issued Reset command	17. PMS confirms the power is available from 11 KV and 440 VAC Distribution	11.PMS
12.	18. Thruster Aux systems including steering drives activated	18. Column Xfmrs feeding Thruster MCC's and feeder breakers closed	12.PMS
13.	19. Thruster issued start command	19. PMS confirms the aux systems have completed the external interlocks to allow operation	13.PMS

14.	20. Thruster Drive confirms no interlocks and closes circuit breaker	20. Thruster drive responds to command and charges capacitors preparing system to produce Ready	14.Thruster Drive
15.	21. Thruster Drive completes start-up	21. Thruster Drive communicates Ready Status to DP system	15.Thruster Drive
16.	22. DP system enables available thrusters automatically	22. In Auto Position Mode, DP system enables available thrusters automatically (note2)	16.K-POS
17.	23. All thrusters on line	23. In Auto Position Mode, DP system enables available thrusters automatically and thrusters are on line and in DP-mode (note2)	17.K-POS
18.	24. Tie between 11 KV Swbd closed	24. After things have settled down the system interconnection will be restored at the ECR	18.Duty Engineer

In case of a partial blackout, the reconnection sequence will be limited to connecting the generators back on the dead bus and connect associated consumers.

Note 1: All transformers pre-magnetizing failure signal will be connected to IAS. During normal operations, a pre-magnetizing failure should interlock the transformer breaker from closing until a minimum of 2 engines are online. However during a blackout recovery, where there will be a 6 split mode, the transformer breaker should be allowed to be closed, even with pre-magnetizing failure. In other cases, circuit breakers shall not be closed before sufficient generators are running.

Note 2:
In normal operation, all thrusters can be manually enabled/disabled by the operator, if their ready signal is present. However, at blackout, the DP system will automatically enable all available thrusters during blackout recovery. The ICS will monitor the blackout recovery of the generators and thrusters as they are recovered and made available for DP. During this process, the ICS will send a blackout recovery signal to the DP system which will continuously enable thrusters as soon as their ready signals become present. When the blackout recovery is seen by the ICS as complete, the blackout recovery signal will be cancelled and the DP system will return to normal operation whereby the operator can manually enable/disable thrusters. Thrusters will only be automatically enabled when the **DP system is in Auto Position mode.**
Be aware that all thrusters that are started and become ready for DP during the blackout recovery will be enabled automatically, irrespective of their status on DP before the blackout. Thrusters that are ready cannot be deselected during the recovery procedure, and thrusters that are not ready, or become ready after the procedure is finished, will not be automatically enabled.

2.7.4 Reconnection of engine room auxiliaries

Essential engine room auxiliaries i.e. motor, fans and pumps will automatically be reconfigured according to the state they were before the blackout occurred. When the power has been restored on the switchboard the motors will be restarted with an individual start delay to avoid high inrush current.

In the event of a partial blackout on the 440V system and the master pump have tripped, the standby pump will automatically start. If power is available for that pump. When power is restored the master pump will restart and some seconds later the standby pump will automatically stop, thus restoring the situation before blackout.

Typical equipment that will be restarted by the software.

Hull Side:

I/O TAG	SERVICE DESCRIPTION	New Restart t delay (s)	SWBD	Power (kW)
MIC-063106	PORT E/R MAIN C.S.W PUMP NO.1	0	AFT PORT 440V SWBD	64,0
MIC-063107	PORT E/R MAIN C.S.W PUMP NO.2	0	AFT PORT 440V SWBD	64,0
MIC-063109	CENT E/R MAIN C.S.W PUMP NO.1	0	AFT CENT 440V SWBD	64,0
MIC-063110	CENT E/R MAIN C.S.W PUMP NO.2	0	AFT CENT 440V SWBD	64,0
MIC-063112	STBD E/R MAIN C.S.W PUMP NO.1	0	AFT STBD 440V SWBD	64,0
MIC-063113	STBD E/R MAIN C.S.W PUMP NO.2	0	AFT STBD 440V SWBD	64,0
MIC-063243	PORT E/R MAIN LOW TEMP C.F.W PUMP NO.1	5	CENT BOW THR AUX PANEL	30,0
MIC-063244	PORT E/R MAIN LOW TEMP C.F.W PUMP NO.2	5	AFT PORT 440V SWBD	30,0
MIC-063263	CENT E/R MAIN LOW TEMP C.F.W PUMP NO.1	5	STBD BOW THR AUX PANEL	30,0
MIC-063264	CENT E/R MAIN LOW TEMP C.F.W PUMP NO.2	5	AFT CENT 440V SWBD	30,0
MIC-063253	STBD E/R MAIN LOW TEMP C.F.W PUMP NO.1	5	PORT BOW THR AUX PANEL	30,0
MIC-063254	STBD E/R MAIN LOW TEMP C.F.W PUMP NO.2	5	AFT STBD 440V SWBD	30,0
MIC-021702	FWD AUX CSW PUMP NO.1	0	FWD 440V SWBD 1	58,0
MIC-021703	FWD AUX CSW PUMP NO.2	0	FWD 440V SWBD 2	58,0
MIC-021604	FWD AUX CFW PUMP NO.1	5	FWD 440V SWBD 1 *	185,0
MIC-021605	FWD AUX CFW PUMP NO.2	5	FWD 440V SWBD 2 *	185,0
MIC-021606	FWD AUX CFW PUMP NO.3	5	EMCY SWBD *	185,0
MIC-022702	PORT BOW THRUSTER ROOM CSW PUMP NO.1	5	PORT BOW THR AUX PANEL	15,0
MIC-022703	PORT BOW THRUSTER ROOM CSW PUMP NO.2	5	PORT BOW THR AUX PANEL	15,0
MIC-023702	STBD BOW THRUSTER ROOM CSW PUMP NO.1	5	STBD BOW THR AUX PANEL	15,0
MIC-023703	STBD BOW THRUSTER ROOM CSW PUMP NO.2	5	STBD BOW THR AUX PANEL	15,0
MIC-022604	PORT BOW THRUSTER ROOM CFW PUMP NO.1	5	PORT BOW THR AUX PANEL	15,0
MIC-022605	PORT BOW THRUSTER ROOM CFW PUMP NO.2	5	PORT BOW THR AUX PANEL	15,0
MIC-023604	STBD BOW THRUSTER ROOM CFW PUMP NO.1	5	STBD BOW THR AUX PANEL	15,0
MIC-023605	STBD BOW THRUSTER ROOM CFW PUMP NO.2	5	STBD BOW THR AUX PANEL	15,0
MIC-042110	CENTER E/R F.W TRANSFER PUMP	40	AFT CENT 440V SWBD	3,0
MIC-042114	STBD E/R F.W TRANSFER PUMP	40	AFT STBD 440V SWBD	3,0
MIC-042124	HOT W. CIRC. PUMP NO.1	Remote manual	FWD 440V SWBD 1	0,37
MIC-042125	HOT W. CIRC. PUMP NO.2	Remote manual	FWD 440V SWBD 2	0,37
MIC-081201	FWD BILGE & GS PUMP NO.1	0	FWD 440V SWBD 1	99,0
MIC-081202	FWD BILGE & GS PUMP NO.2	0	FWD 440V SWBD 2	99,0
MIC-081204	PORT E/R BALLAST, BILGE & GS PUMP	30	AFT PORT 440V SWBD *	288,0
MIC-081208	STBD E/R BALLAST, BILGE & GS PUMP	30	AFT STBD 440V SWBD *	288,0
MIC-091801	FWD FIRE PUMP	10	EMCY SWBD *	450,0
MIC-091811	AFT PORT FIRE PUMP	10	AFT PORT 440V SWBD *	450,0
MIC-091821	AFT STBD FIRE PUMP	10	AFT STBD 440V SWBD *	450,0
MIC-091831	FIRE JOCKEY PUMP NO.1	0	FWD 440V SWBD 1	35,0
MIC-091832	FIRE JOCKEY PUMP NO.2	0	FWD 440V SWBD 2	35,0
MIC-042401	DRILLING WATER PUMP NO.1	20	FWD 440V SWBD 1	70,0
MIC-042402	DRILLING WATER PUMP NO.2	20	FWD 440V SWBD 2	70,0
MIC-042112	AFT E/R F.W HYD PUMP NO.1	60	AFT CENT 440V SWBD	3,0
MIC-042113	AFT E/R F.W HYD PUMP NO.2	60	AFT CENT 440V SWBD	3,0
MIC-042120	FWD AUX MACH. ROOM FW HYD PUMP NO.1	70	FWD 440V SWBD 1	15,0
MIC-042121	FWD AUX MACH. ROOM FW HYD PUMP NO.2	70	FWD 440V SWBD 2	15,0
MIC-111101	BALLAST PUMP NO.1	60	AFT PORT 440V SWBD *	355,0
MIC-111201	BALLAST PUMP NO.2	60	AFT STBD 440V SWBD *	355,0

MIC-081225	DRAIN PUMP NO.1	90	AFT PORT 440V SWBD	55,0
MIC-081235	DRAIN PUMP NO.2	90	AFT STBD 440V SWBD	55,0
MIC-052151	PORT E/R LO TRANSFER PUMP	30	AFT PORT 440V SWBD	2,5
MIC-052351	STBD E/R LO TRANSFER PUMP	30	AFT STBD 440V SWBD	2,5
MIC-081203	FWD AUX. MACH. ROOM BILGE PUMP	Remote manual	FWD 440V SWBD 2	3,6
MIC-081207	AFT CENT E/R BILGE PUMP	Remote manual	AFT CENT 440V SWBD	3,6
MIC-073201	PORT E/R M.D.O TRANSFER PUMP FOR TOPSIDE	40	AFT PORT 440V SWBD	4,6
MIC-073202	STBD E/R M.D.O TRANSFER PUMP FOR TOPSIDE	40	AFT STBD 440V SWBD	4,6
MIC-072102	PORT E/R M.D.O TRANSFER PUMP	30	AFT PORT 440V SWBD	8,6
MIC-072104	STBD E/R M.D.O TRANSFER PUMP	30	AFT STBD 440V SWBD	8,6
MIC-011407	PORT E/R M.D.O SUPPLY PUMP NO.1	0	AFT STBD 440V SWBD	3,5
MIC-012407	PORT E/R M.D.O SUPPLY PUMP NO.2	0	CENT BOW THR AUX PANEL	3,5
MIC-013407	CENTER E/R M.D.O SUPPLY PUMP NO.1	0	AFT PORT 440V SWBD	3,5
MIC-014407	CENTER E/R M.D.O SUPPLY PUMP NO.2	0	STBD BOW THR AUX PANEL	3,5
MIC-015407	STBD E/R M.D.O SUPPLY PUMP NO.1	0	AFT CENT 440V SWBD	3,5
MIC-016407	STBD E/R M.D.O SUPPLY PUMP NO.2	0	PORT BOW THR AUX PANEL	3,5
MIC-061201	PORT E/R G/S AIR COMPRESSOR NO.1	0	AFT PORT 440V SWBD *	288,0
MIC-061202	PORT E/R G/S AIR COMPRESSOR NO.2	0	AFT PORT 440V SWBD *	288,0
MIC-061221	STBD E/R G/S AIR COMPRESSOR NO.1	0	AFT STBD 440V SWBD *	288,0
MIC-061222	STBD E/R G/S AIR COMPRESSOR NO.2	0	AFT STBD 440V SWBD *	288,0
MIC-061101	PORT E/R STARTING AIR COMPRESSOR	0	AFT PORT 440V SWBD *	45,0
MIC-061111	CENTER E/R STARTING AIR COMPRESSOR	0	EMCY SWBD *	45,0
MIC-061121	STBD E/R STARTING AIR COMPRESSOR	0	AFT STBD 440V SWBD *	45,0
MIC-062606	PORT E/R SUP. FAN NO.1	0	AFT PORT 440V SWBD	37,0
MIC-062607	PORT E/R SUP. FAN NO.2	0	EMCY SWBD *	37,0
MIC-062610	CENT E/R SUP. FAN NO.1	0	AFT CENT 440V SWBD	37,0
MIC-062611	CENT E/R SUP. FAN NO.2	0	EMCY SWBD *	37,0
MIC-062613	STBD E/R SUP. FAN NO.1	0	AFT STBD 440V SWBD	37,0
MIC-062614	STBD E/R SUP. FAN NO.2	0	EMCY SWBD *	37,0
MIC-062603	CENT BOW THRUSTER ROOM SUP. FAN	0	CENT BOW THR AUX PANEL	5,5
MIC-062604	PORT BOW THRUSTER ROOM SUP. FAN	0	PORT BOW THR AUX PANEL	5,5
MIC-062605	STBD BOW THRUSTER ROOM SUP. FAN	0	STBD BOW THR AUX PANEL	7,5
MIC-062606	PORT STERN THRUSTER ROOM SUP. FAN	0	PORT STERN THR AUX PANEL	5,5
MIC-062615	STBD STERN THRUSTER ROOM SUP. FAN	0	STBD STERN THR AUX PANEL	5,5
MIC-062612	CENT STERN THRUSTER ROOM SUP. FAN	0	CENT STERN THR AUX PANEL	5,5
MIC-062601	FWD AUX MACH. ROOM SUP. FAN NO.1	0	FWD 440V SWBD 1	5,5
MIC-062602	FWD AUX MACH. ROOM SUP. FAN NO.2	0	EMCY SWBD *	5,5
MIC-021212	CENT BOW THRUSTER TR COOLING FAN 1	0	CENT BOW THR AUX PANEL	3,6
MIC-021213	CENT BOW THRUSTER TR COOLING FAN 2	0	CENT BOW THR AUX PANEL	3,6
MIC-021211	CENT BOW THRUSTER MOTOR COOLING FAN	0	CENT BOW THR AUX PANEL	17,2
MIC-021301	CENT BOW THR PRIMARY LO PUMP	5	CENT BOW THR AUX PANEL	4,4
MIC-021301	CENT BOW THR SECONDARY LO PUMP	5	CENT BOW THR AUX PANEL	1,65
MIC-021401	CENT BOW THR STEERING PUMP 1	5	CENT BOW THR AUX PANEL	99,0
MIC-021402	CENT BOW THR STEERING PUMP 2	5	CENT BOW THR AUX PANEL	99,0
MIC-022212	PORT BOW THRUSTER TR COOLING FAN 1	0	PORT BOW THR AUX PANEL	3,6

MIC-022213	PORT BOW THRUSTER TR COOLING FAN 2	0	PORT BOW THR AUX PANEL	3,6
MIC-022211	PORT BOW THRUSTER MOTOR COOLING FAN	0	PORT BOW THR AUX PANEL	17,2
MIC-022301	PORT BOW THR PRIMARY LO PUMP	5	PORT BOW THR AUX PANEL	4,4
MIC-022301	PORT BOW THR SECONDARY LO PUMP	5	PORT BOW THR AUX PANEL	1,65
MIC-022401	PORT BOW THR STEERING PUMP 1	5	PORT BOW THR AUX PANEL	99,0
MIC-022402	PORT BOW THR STEERING PUMP 2	5	PORT BOW THR AUX PANEL	99,0
MIC-023212	STBD BOW THRUSTER TR COOLING FAN 1	0	STBD BOW THR AUX PANEL	3,6
MIC-023213	STBD BOW THRUSTER TR COOLING FAN 2	0	STBD BOW THR AUX PANEL	3,6
MIC-023211	STBD BOW THRUSTER MOTOR COOLING FAN	0	STBD BOW THR AUX PANEL	17,2
MIC-023301	STBD BOW THR PRIMARY LO PUMP	5	STBD BOW THR AUX PANEL	4,4
MIC-023301	STBD BOW THR SECONDARY LO PUMP	5	STBD BOW THR AUX PANEL	1,65
MIC-023401	STBD BOW THR STEERING PUMP 1	5	STBD BOW THR AUX PANEL	99,0
MIC-023402	STBD BOW THR STEERING PUMP 2	5	STBD BOW THR AUX PANEL	99,0
MIC-024212	PORT STERN THRUSTER TR COOLING FAN 1	0	PORT STERN THR AUX PANEL	3,6
MIC-024213	PORT STERN THRUSTER TR COOLING FAN 2	0	PORT STERN THR AUX PANEL	3,6
MIC-024211	PORT STERN THRUSTER MOTOR COOLING FAN	0	PORT STERN THR AUX PANEL	17,2
MIC-024301	PORT STERN THR PRIMARY LO PUMP	5	PORT STERN THR AUX PANEL	4,4
MIC-024301	PORT STERN THR SECONDARY LO PUMP	5	PORT STERN THR AUX PANEL	1,65
MIC-024401	PORT STERN THR STEERING PUMP 1	5	PORT STERN THR AUX PANEL	99,0
MIC-024402	PORT STERN THR STEERING PUMP 2	5	PORT STERN THR AUX PANEL	99,0
MIC-025212	STBD STERN THRUSTER TR COOLING FAN 1	0	STBD STERN THR AUX PANEL	3,6
MIC-025213	STBD STERN THRUSTER TR COOLING FAN 2	0	STBD STERN THR AUX PANEL	3,6
MIC-025211	STBD STERN THRUSTER MOTOR COOLING FAN	0	STBD STERN THR AUX PANEL	17,2
MIC-025301	STBD STERN THR PRIMARY LO PUMP	5	STBD STERN THR AUX PANEL	4,4
MIC-025301	STBD STERN THR SECONDARY LO PUMP	5	STBD STERN THR AUX PANEL	1,65
MIC-025401	STBD STERN THR STEERING PUMP 1	5	STBD STERN THR AUX PANEL	99,0
MIC-025402	STBD STERN THR STEERING PUMP 2	5	STBD STERN THR AUX PANEL	99,0
MIC-026212	CENT STERN THRUSTER TR COOLING FAN 1	0	CENT STERN THR AUX PANEL	3,6
MIC-026213	CENT STERN THRUSTER TR COOLING FAN 2	0	CENT STERN THR AUX PANEL	3,6
MIC-026211	CENT STERN THRUSTER MOTOR COOLING FAN	0	CENT STERN THR AUX PANEL	17,2
MIC-026301	CENT STERN THR PRIMARY LO PUMP	5	CENT STERN THR AUX PANEL	4,4
MIC-026301	CENT STERN THR SECONDARY LO PUMP	5	CENT STERN THR AUX PANEL	1,65
MIC-026401A	CENT STERN THR STEERING PUMP 1	5	CENT STERN THR AUX PANEL	99,0
MIC-026402	CENT STERN THR STEERING PUMP 2	5	CENT STERN THR AUX PANEL	99,0
MIC-062608	PORT PURIFIER ROOM EXH. FAN	0	AFT PORT 440V SWBD	5,5

MIC-062616	STBD PURIFIER ROOM EXH. FAN	0	AFT STBD 440V SWBD	5,5
MIC-062625	WELDING SPACE EXH. FAN	Manual	AFT CENT 440V SWBD *	0,43
MIC-062624	INCINERATOR SUP. FAN	70	AFT STBD 440V SWBD	3,7
MIC-062901	UNIT COOLER NO.1 FOR ECR	40	AFT PORT 440V SWBD	12,6
MIC-062902	UNIT COOLER NO.2 FOR ECR	40	AFT CENT 440V SWBD	12,6
MIC-062930	UNIT COOLER NO.1 FOR PORT MSBD ROOM	20	AFT PORT 440V SWBD	12,6
MIC-062931	UNIT COOLER NO.1 FOR CENTER MSBD ROOM	20	AFT CENT 440V SWBD	12,6
MIC-062932	UNIT COOLER NO.1 FOR STBD MSBD ROOM	20	AFT STBD 440V SWBD	12,6
MIC-062927	UNIT COOLER NO.2 FOR PORT MSBD ROOM	20	AFT PORT 440V SWBD	12,6
MIC-062928	UNIT COOLER NO.2 FOR CENTER MSBD ROOM	20	AFT CENT 440V SWBD	12,6
MIC-062929	UNIT COOLER NO.2 FOR STBD MSBD ROOM	20	AFT STBD 440V SWBD	12,6
MIC-062903	CENT BOW THRUSTER ROOM UNIT COOLER NO.1	30	CENT BOW THR AUX PANEL	10,65
MIC-062904	CENT BOW THRUSTER ROOM UNIT COOLER NO.2	30	CENT BOW THR AUX PANEL	10,65
MIC-062905	CENT BOW THRUSTER ROOM UNIT COOLER NO.3	40	CENT BOW THR AUX PANEL	10,65
MIC-062906	CENT BOW THRUSTER ROOM UNIT COOLER NO.4	40	CENT BOW THR AUX PANEL	10,65
MIC-062907	PORT BOW THRUSTER ROOM UNIT COOLER NO.1	30	PORT BOW THR AUX PANEL	10,65
MIC-062908	PORT BOW THRUSTER ROOM UNIT COOLER NO.2	30	PORT BOW THR AUX PANEL	10,65
MIC-062909	PORT BOW THRUSTER ROOM UNIT COOLER NO.3	40	PORT BOW THR AUX PANEL	10,65
MIC-062910	PORT BOW THRUSTER ROOM UNIT COOLER NO.4	40	PORT BOW THR AUX PANEL	10,65
MIC-062911	STBD BOW THRUSTER ROOM UNIT COOLER NO.1	30	STBD BOW THR AUX PANEL	10,65
MIC-062912	STBD BOW THRUSTER ROOM UNIT COOLER NO.2	30	STBD BOW THR AUX PANEL	10,65
MIC-062913	STBD BOW THRUSTER ROOM UNIT COOLER NO.3	40	STBD BOW THR AUX PANEL	10,65
MIC-062914	STBD BOW THRUSTER ROOM UNIT COOLER NO.4	40	STBD BOW THR AUX PANEL	10,65
MIC-062915	PORT STERN THRUSTER ROOM UNIT COOLER NO.1	30	PORT STERN THR AUX PANEL	10,65
MIC-062916	PORT STERN THRUSTER ROOM UNIT COOLER NO.2	30	PORT STERN THR AUX PANEL	10,65
MIC-062917	PORT STERN THRUSTER ROOM UNIT COOLER NO.3	40	PORT STERN THR AUX PANEL	10,65
MIC-062918	PORT STERN THRUSTER ROOM UNIT COOLER NO.4	40	PORT STERN THR AUX PANEL	10,65
MIC-062919	STBD STERN THRUSTER ROOM UNIT COOLER NO.1	30	STBD STERN THR AUX PANEL	10,65
MIC-062920	STBD STERN THRUSTER ROOM UNIT COOLER NO.2	30	STBD STERN THR AUX PANEL	10,65
MIC-062921	STBD STERN THRUSTER ROOM UNIT COOLER NO.3	40	STBD STERN THR AUX PANEL	10,65
MIC-062922	STBD STERN THRUSTER ROOM UNIT COOLER NO.4	40	STBD STERN THR AUX PANEL	10,65
MIC-062923	CENT STERN THRUSTER ROOM UNIT COOLER NO.1	30	CENT STERN THR AUX PANEL	10,65
MIC-062924	CENT STERN THRUSTER ROOM UNIT COOLER NO.2	30	CENT STERN THR AUX PANEL	10,65
MIC-062925	CENT STERN THRUSTER ROOM UNIT COOLER NO.3	40	CENT STERN THR AUX PANEL	10,65

MIC-062926	CENT STERN THRUSTER ROOM UNIT COOLER NO.4	40	CENT STERN THR AUX PANEL	10,65
MIC-062678A	LAUNDRY EXH. FAN	90	HVAC MCC 1	2,2
MIC-062676A	BATTERY ROOM NO.1 EXH. FAN	0	HVAC MCC EMCY	0,75
MIC-062676A	BATTERY ROOM NO.2 EXH. FAN	0	HVAC MCC EMCY	0,75
MIC-062674A	LIFT M/C ROOM EXH. FAN	90	HVAC MCC 1	0,75
MIC-062671A	AHU ROOM EXH. FAN	60	HVAC MCC 1	1,5
MIC-062668A	DRY PROVISION STORE EXH. FAN	90	HVAC MCC 1	0,75
MIC-062673A	HOSPITAL EXH. FAN	90	HVAC MCC EMCY	0,304
MIC-062664A	SANITARY SPACE EHX. FAN NO.1	90	HVAC MCC 2	1,73
MIC-062661A	AHU FAN NO.1	60	HVAC MCC 1	55,0
MIC-062662A	AHU FAN NO.2	60	HVAC MCC 2	55,0
MIC-062649A	AHU FAN NO.3	60	HVAC MCC 1	55,0
MIC-062669A	RECIRCULATION FAN NO.1	60	HVAC MCC 1	15,0
MIC-062670A	RECIRCULATION FAN NO.2	60	HVAC MCC EMCY	15,0
MIC-062650A	RECIRCULATION FAN NO.3	60	HVAC MCC 1	15,0
MIC-062639A	RECREATION ROOM EXH. FAN	90	HVAC MCC 1	0,75
MIC-062677A	SANITARY SPACE EHX. FAN NO.2	90	HVAC MCC 2	0,63
MIC-062678A	EM'CY GEN. ROOM EXH. FAN	0	HVAC MCC EMCY	1,5
MC-062642A	W/H UNIT COOLER	40	EMCY SWBD	8,7
MC-062641A	HELI-DK RECEPTION ROOM UNIT COOLER	90	EMCY SWBD	3,9
MIC-062620A	BOSUN STORE SUPPLY FAN	90	FWD 440V SWBD 1 *	2,2
MIC-062628A	DRY BULK TANK EXH FAN NO.1	90	FWD 440V SWBD 1 *	11,0
MIC-062629A	DRY BULK TANK EXH FAN NO.2	90	FWD 440V SWBD 2 *	11,0
MIC-062623A	AGITATOR SPACE EXH FAN	0	FWD 440V SWBD 2 *	4,0
MIC-062656A	AFT PORT HPR COMP SUPPLY FAN	90	AFT PORT 440V SWBD	0,75
MIC-062658A	AFT STBD HPR COMP SUPPLY FAN	90	AFT STBD 440V SWBD	0,75
MIC-062619A	BALLAST PUMP ROOM EXH. FAN NO.1	60	AFT PORT 440V SWBD	15,0
MIC-062630A	BALLAST PUMP ROOM EXH. FAN NO.2	60	AFT STBD 440V SWBD	15,0
MIC-062627A	HYD. POWER PACK ROOM SUP. FAN 1	60	EMCY SWBD *	4,6
MIC-062626A	WATER MIST & INERGEN ROOM SUPPLY FAN	60	EMCY SWBD *	0,4
MIC-062622A	FWD STBD HPR COMP SUPPLY FAN	90	FWD 440V SWBD 1 *	0,75
MIC-062621A	FWD PORT HPR COMP SUPPLY FAN	90	FWD 440V SWBD 2 *	0,75
MIC-062659A	FWD PORT SECONDARY ESCAPE WAY SUPPLY FAN	60	FWD 440V SWBD 1 *	1,5
MIC-062660A	FWD STBD SECONDARY ESCAPE WAY SUPPLY FAN	60	FWD 440V SWBD 2 *	1,5
MIC-062655A	AFT PORT SECONDARY ESCAPE WAY SUPPLY FAN	60	AFT PORT 440V SWBD	1,5
MIC-062657A	AFT STBD SECONDARY ESCAPE WAY SUPPLY FAN	60	AFT STBD 440V SWBD	1,5

Topside:

SWBD No.	EQUIP. Tag	EQUIPMENT DESC	AIM TAG	DELAY TIME IN SEC
=871-Q2/EN001	311U1E1/IB001	HVAC CONTROL CABINET		0

=871-Q2/EN001	311U1E1/GI150A	AC-UNIT FOR DC/LIR		0
=871-Q2/EN001	865T3/ET001	200kVA 440/235V TRNASFORMER No.1		0
=871-Q2/EN001	3D86004	SACK STORAGE AREA A/C PACKAGE UNIT	MIC-062817	0
=871-Q2/EN001	3D86008	SUBSEA WORKSHOP REDUNDANCY A/C PACKAGE UNIT		0
=871-Q2/EN001	3D86002A	SWGR AHU COMPRESSOR A		0
=871-Q2/EN001	3D86001A	DRILLING SWITCHGEAR ROOM AHU A FAN MOTOR	MIC-062701	0
=871-Q2/EN001	3D86011	COFFEE SHOP EXTRACT FAN	MIC-062789	0
=871-Q2/EN001	3D86013	DRILLING SWITCHGEAR ROOM EXTRACT FAN	MIC-062753	0
=871-Q2/EN001	3D86016A	MUD TANK AREA SUPPLY FAN No.1	MIC-062733	0
=871-Q2/EN001	3D86017A	MUD TANK AREA EXTRACT FAN No.1	MIC-062737	0
=871-Q2/EN001	3D86018A	MUD TANKS EXTRACT FAN No.1	MIC-062741	0
=871-Q2/EN001	3D86021A	SACK STORAGE AREA SUPPLY FAN No.1	MIC-062717	0
=871-Q2/EN001	3D86022A	SACK STORAGE AREA EXTRACT FAN No.1	MIC-062721	0
=871-Q2/EN001	3D86025A	MUD CUTTINGS & TRANSFER SUPPLY FAN No.1	MIC-062767	0
=871-Q2/EN001	3D86026A	MUD CUTTINGS & TRANSFER EXTRACT FAN No.1	MIC-062771	0
=871-Q2/EN001	3D86029	MAIN HPU ROOM EXTRACT FAN	MIC-062777	0
=871-Q2/EN001		6.5MVA VFD TRANSFORMER NO.1 MAIN COOLING FAN		0
=871-Q2/EN001		6.5MVA VFD TRANSFORMER NO.1 AUX. COOLING FAN		0
=871-Q2/EN002	865T3/ET002	200kVA 440/235V TRNASFORMER No.2	MIC-062806	0
=871-Q2/EN002	3D86003	WORKSHOP A/C PACKAGE UNIT	MIC-062804	0

=871-Q2/EN002	3D86006	SHALE SHAKER OPERATION ROOM A/C PACKAGE UNIT	MIC-062805	0
=871-Q2/EN002	3D86007	POD TEST ROOM A/C PACKAGE UNIT		0
=871-Q2/EN002	3D86002C	SWGR AHU COMPRESSOR C		0
=871-Q2/EN002	3D86001B	DRILLING SWITCHGEAR ROOM AHU B FAN MOTOR	MIC-062703	0
=871-Q2/EN002	3D86016B	MUD TANK AREA SUPPLY FAN No.2	MIC-062735	0
=871-Q2/EN002	3D86017B	MUD TANK AREA EXTRACT FAN No.2	MIC-062739	0
=871-Q2/EN002	3D86021B	SACK STORAGE AREA SUPPLY FAN No.2	MIC-062719	0
=871-Q2/EN002	3D86022B	SACK STORAGE AREA EXTRACT FAN No.2	MIC-062723	0
=871-Q2/EN002	3D86027B	SHALE SHAKER AREA SUPPLY FAN No.2	MIC-062761	0
=871-Q2/EN002	3D86028B	SHALE SHAKER AREA EXTRACT FAN No.2	MIC-062765	0
=871-Q2/EN002	3D86030	BOP EQUIPMENT ROOM SUPPLY FAN	MIC-062785	0
=871-Q2/EN002	3D86031	BOP EQUIPMENT ROOM EXTRACT FAN	MIC-062787	0
=871-Q2/EN002	3D86038	WELDING WORKSHOP EXTRACT FAN	MIC-062755	0
=871-Q2/EN002	3D86039	WELDING WORKSHOP EXTRACT FAN	MIC-062757	0
=871-Q2/EN002		6.5MVA VFD TRANSFORMER NO.2 MAIN COOLING FAN		0
=871-Q2/EN002		6.5MVA VFD TRANSFORMER NO.2 AUX. COOLING FAN		0
=871-Q2/EN003	311U1E1/GI150B	AC-UNIT FOR DC		0
=871-Q2/EN003	311U1E1/GI150D	AC-UNIT FOR TDCR		0
=871-Q2/EN003	311U1E1/GI150C	AC-UNIT FOR LIR		0
=871-Q2/EN003	3D86005	SUBSEA WORKSHOP A/C PACKAGE UNIT		0

=871-Q2/EN003	3D86040	MUD LAB EXTRACT FAN		0
=871-Q2/EN003	3D86002B	SWGR AHU COMPRESSOR B		0
=871-Q2/EN003	3D86001C	DRILLING SWITCHGEAR ROOM AHU C FAN MOTOR	MIC-062815	0
=871-Q2/EN003	3D86012	HVAC ROOM EXTRACT FAN	MIC-062791	0
=871-Q2/EN003	3D86014	MUD MODULE WAREHOUSE SUPPLY FAN	MIC-062705	0
=871-Q2/EN003	3D86015	MUD MODULE WAREHOUSE EXTRACT FAN	MIC-062707	0
=871-Q2/EN003	3D86018B	MUD TANKS EXTRACT FAN No.2	MIC-062743	0
=871-Q2/EN003	3D86023	CEMENTER ROOM SUPPLY FAN	MIC-062725	0
=871-Q2/EN003	3D86024	CEMENTER ROOM EXTRACT FAN	MIC-062729	0
=871-Q2/EN003	3D86025B	MUD CUTTING & TRANSFER SUPPLY FAN No.2	MIC-062769	0
=871-Q2/EN003	3D86026B	MUD CUTTING & TRANSFER EXTRACT FAN No.2	MIC-062773	0
=871-Q2/EN003	3D86027A	SHALE SHAKER AREA SUPPLY FAN No.1	MIC-062759	0
=871-Q2/EN003	3D86028A	SHALE SHAKER AREA EXTRACT FAN No.1	MIC-062763	0
=871-Q2/EN003	3D86032	SUBSEA MODULE - APV ROOM SUPPLY FAN	MIC-062781	0
=871-Q2/EN003	3D86033	SUBSEA MODULE - APV ROOM EXTRACT FAN	MIC-062783	0
=871-Q2/EN003		6.5MVA VFD TRANSFORMER NO.3 MAIN COOLING FAN		0
=871-Q2/EN003		6.5MVA VFD TRANSFORMER NO.3 AUX. COOLING FAN		0

3 Main Generator Engine Control

The six (6) main diesel engines are delivered by Doosan ManDiesel SE Augsburg and are of type 16V32/40. The engines are fitted with Woodward speed governor. Rated engine speed is 720 RPM.

The main control functions for the main diesel engines are as follows:

- Engines start & stop, automatically from PMS.
- Pre-lubrication of the engine.(LCP)
- Preheating of the engine.(LCP)

Alarm and monitoring of the engine.(In PMS via a Modbus serial line from LCP)

3.1 Ambient Conditions

The equipment is designed for the following conditions:

Maximum ambient air temperature:	max.45degC
Minimum charge air temperature:	min -20degC
Maximum LT cooling water temperature before engine:	38degC
Maximum sea water temperature:	32degC
Relative humidity:	60%

3.2 Diesel Engine Speed Detection

The engine speed is detected by means of a non-contact, inductive proximity switch. The frequency from this sensor, which is proportional to engine speed, is converted to a voltage. This voltage signal is connected to three individually adjustable relays. These relays have all been pre-adjusted at factory.

- Relay 1 – set at 300 RPM “engine running idle”
- Relay 2 – set at 90% of nominal speed 648 RPM “engine running rated”
- Relay 3 – set at over speed set point (814 RPM)

PMS are only receiving a running rated signal from engine.

3.3 Diesel Engine Start

The engine has a control station mounted on engine with a mode selector. The functions for this mode selector are:

- **Remote** (XI-011130) + Control position selector switch in Swbd (XI-011137) is selected as :-

- **1. IAS Control**: Engine can be started and stopped only from IAS.

- **2. SWBD Control**: Engine can be started and stopped only from SWBD.

- **Ready to Start** (XI-011132): This signal is generated by Main engine and it should be active for normal start of engine either from local or remote, without this signal engine start is not possible. However Emergency start is still possible by operating the mechanical button on the start solenoid valve.

Main diesel engine start sequence is initiated either upon a manual start order from an operator station, or automatically, provided that the engine is in STANDBY mode, as a result of:

- Start request from operator station
- Load dependent start from power management system (PMS, if the generator is in *standby* mode)
- Bus bar blackout (if the generator is in *standby* mode)
- Safety system of any connected generator activated (if the generator is in *standby* mode)
- Standby start failure (start fail, voltage not established, synchronising failure)
- Generator changeover caused by alarm on generator in operation
- Low frequency below 54 Hz
- Power consumed IO-failure on power used from drilling

A start failure alarm is given if PMS has tried to start the engine three times. This parameter can be changed by advanced users (password protected). A start failure alarm is also given if the Start Fail signal from Doosan is activated. The engine will be blocked from starting until manual reset on PMS mimic.

The time between each start attempt is set to be 0 sec. The time can be modified by advanced users (password protected).

Upon an automatic start request from PMS and the engine fails to start once, the start sequence of the next standby engine will be initiated immediately. This applies when one or more switchboards are connected together.

Upon a successful start the generator voltage would normally rise to rated voltage. If rated voltage is not established within 20 seconds after engine start, an alarm is generated. In the event of an automatic start request, the next standby engine will start.

RPM failure alarm is generated if engine-running indication disappears while generator voltage is normal and generator breaker is closed.

As the fuel pump for this engine is an external pump, PMS shall first give start command to the fuel pump if it is not running (MC-062606).

The remote start signal is a time relay function, which allows the start signal to be given for a maximum of 20 seconds. If the engine is automatically started by a stand-by start signal and “engine run” signal is not got within 30 seconds, then the next stand-by engine is started.

In Engine Standby Mode, pre lubrication pressure will be maintained by Engine Controller (>0.3bar). If pre-lubrication pressure is under 0.3bar, then pre-lubrication pump will started to maintain pressure.

3.3.1 Start Blocking

Start is inhibited by the following functions:

- **Engine start block conditions:**

Description	Tag	Limit	Remark	Trig to “No Standby”
Ready to Start (*Ref vendor for details)	XI-011132		From Local panel. Start block active, if ready signal not receive	Keep Standby Number
MGE in Remote control	XI-011130		Should be selected remote mode in LCP	Trig to No Standby
MGE breaker tripped	XA-031106		Start block active, trip active.	Trig to No Standby
Start failure reset	SOW			Keep Standby Number
Safety shutdown cause reset	SOW			Trig to No Standby
MGEN Ready for Start From SWBD	XI-031108		Start block active, if ready signal not receive	Keep Standby Number

Table 3.3-1 Main diesel engine start block conditions

*"Ready to Start" conditions (checked internally in Engine Control Panel):

- Engine not running

- Pre LO press OK

- Turning Gear dis-engage

- Engine in Remote mode

- No shutdown activated-

3.3.2 Start Air Cutting

The start signal is cut by:

- Engine running (300 RPM)
- After 4 seconds (time relay)
- Stop signal activated

3.4 Engine Remote Stop

Diesel engine stop sequence is initiated upon a manual stop order from an operator station. If the load dependent stop function is enabled the engine may also be stopped automatically, provided that the engine is in STANDBY mode and that the present power situation allows capacity reduction.

If the remaining generator capacity on a bus after disconnecting a generator will result in overload or blackout, the PMS system will inhibit disconnect of the generators on the bus. This will be indicated in the mimic.

Prior to normal stop of the engine, the generator must be disconnected before stop signal is given. In case of load dependent stop or automatic generator changeover, generator downloading and disconnection is performed automatically by PMS. If the stop sequence is initiated by an operator request, the stop signal will be given immediately after breaker disconnection. In case of a load dependent stop, a cooling down period of 4 minutes between breaker disconnection and engine stop is foreseen.

For normal stop of the main diesel engine, the K-Chief system activates the stop signal XC-011134 to local LCP. Upon this signal engine local LCP will send stop command to engine governor controller; then the governor will set the fuel admission to zero position. The stop signal from the K-Chief system will remain activated one minute after the running signal is lost, i.e. engine revolution<300rpm (XI-011115).

3.4.1 Safety Stop – Shutdown

A shutdown is performed if any of the signal in the table below goes active, and set the start inhibit signal. The start inhibit signal will be present until the cause of shutdown has disappeared and a manual reset has been done.

In the event that any of the parameters in the shutdown conditions table exceeds the specified limit, the engine will be automatically shut down. IAS send stop signal XC-01x134 (x= 1 to 6) to the local control panel; upon receiving this signal local PLC send engine stop signal to Governor Panel.

The engine will be automatically shut down in the following cases:

Engine shutdown conditions:

Description	Tag	Limit	Remark
Main Generator Winding R phase temp	TIAH-031121	H 140 Deg HH 155 Deg	Alarm start at high, trip at high high
Main Generator Winding S phase temp	TIAH-031122	H 140 Deg HH 155 Deg	Alarm start at high, trip at high high
Main Generator Winding T phase temp	TIAH-031123	H 140 Deg HH 145 Deg	Alarm start at high, trip at high high
Main Generator N-end bearing temp	TIAH-031124	H 90 Deg HH 100 Deg	Alarm start at high, trip at high high
Main Generator D-end bearing temp	TIAH-031125	H 90 Deg HH 100 Deg	Alarm start at high, trip at high high
Shutdown by AGS	SOW		See Chapter 7.1
MGEN Shutdown to PMS	XA-011113		Hardwire
MGEN Stop by Gen. Shutdown	XA-011138		Hardwire

The following parameters will initiate a shutdown of port MGE1 from Local control panel, only for monitoring.

Description	Tag	Limit	Remark
OIL Mist in Crankcase Shutdown	Ref. Modbus List		Line monitored by local PLC
Auto Shutdown	Ref. Modbus List		Line monitored by local PLC
Lube Oil Pressure Engine low	Ref. Modbus List		From Shutdown Word 1
Lube Oil Pressure Turbocharger low	Ref. Modbus List		From Shutdown Word 1
Lube oil Temperature after Turbocharger A high	Ref. Modbus List		From Shutdown Word 1
Lube Oil Temperature after Turbocharger B high	Ref. Modbus List		From Shutdown Word 1
Main bearing temperature high	Ref. Modbus List		From Shutdown Word 1
Over speed Engine (Sensor 1)	Ref. Modbus List		From Shutdown Word 2
Over speed Engine (Sensor 2)	Ref. Modbus List		From Shutdown Word 2
EM Driver Failure	Ref. Modbus List		From Shutdown Word 2
Shutdown from HV SWBD	Ref. Modbus List		From Shutdown Word 3
Shutdown from ESD system	Ref. Modbus List		From Shutdown Word 3

Table 3.4-1 Main diesel engine shutdown conditions

All safety stop are done by Doosan LCP . PMS is monitoring the shutdown signals by means of Modbus serial line to engine LCP. KM should have the **Common shutdown** signal as Hard wired to be able to react quickly. A shutdown will start the next standby generator.

Doosan should delay the open signal to the breaker with 0.3 seconds so PMS has time to react on the common local shutdown signal. KM will then do load reduction if it’s necessary, instead of maybe go into an overload situation and then reduce the load after the breaker is tripped.

The combustion air for the engine is taken from the engine room itself. The fresh air intake for the engine room is fitted with two gas detectors for gas alarm only, in the event of confirmed gas detected at the inlet of the engine room the fire damper in the air inlet will be closed by operator via ESD pushbutton panel (ES11) or damper close switch in damper control panel depending on the situation.

The Main Generator engine can be stopped on emergency from 2 locations.

a. From ESD process station in the event of fire in engine room.
b. From the local Emergency stop PB.

Critical shutdown sensors of analogue as well as digital type contain circuit monitoring and an alarm is given in case of short circuit / open circuit.

Override switch for shutdown/alarm Start function (Harbour Mode Switch)

On the K-Thrust OS there is a switch for override the shutdown/Alarm Start signals for the generator. This switch is hardwired direct to FS45. This signal will be transferred over net to all PMS station and also send to Doosan engine.

This override will block all shutdown signals from the IAS and also shutdown signal in the Doosan engine.

This override will also block engine load reduction (change Over) from Engine Control system.

3.5 Diesel Generator – Alarm Start

In the event that any of the parameters in

Engine change-over conditions:

Description	Tag	Limit	Remark
Main Generator Winding R phase temp	TIAH-031121	H 140 Deg HH 155 Deg	Alarm start at high, trip at high high
Main Generator Winding S phase temp	TIAH-031122	H 140 Deg HH 155 Deg	Alarm start at high, trip at high high
Main Generator Winding T phase temp	TIAH-031123	H 140 Deg HH 145 Deg	Alarm start at high, trip at high high
Main Generator N-end bearing temp	TIAH-031124	H 90 Deg HH 100 Deg	Alarm start at high, trip at high high
Main Generator D-end bearing temp	TIAH-031125	H 90 Deg HH 100 Deg	Alarm start at high, trip at high high
Fuel Rack Position Error	ZI-011144	10 %	Inconsistency between Fuel Rack position and engine load.
Load Reduction (Standby Engine Start& Change over) to PMS	XA-011112		Hardwire

The following parameters will initiate a change over of port MGE1 from Local control panel, only for monitoring.

Description	Tag	Limit	Remark
HT Cooling Water Pressure low	Ref. Modbus List		From Reduce Word 1
HT Cooling Water Temperature high	Ref. Modbus List		From Reduce Word 1
Lube Oil Temperature before Engine high	Ref. Modbus List		From Reduce Word 1
Turbocharger Over speed	Ref. Modbus List		From Reduce Word 1
Exhaust Gas Temperature High	Ref. Modbus List		From Reduce Word 1
Exhaust Gas Temperature Mean Value Deviation High	Ref. Modbus List		From Reduce Word 1
Exhaust Gas Temperature Before Turbocharger High	Ref. Modbus List		From Reduce Word 1

Description	Tag	Limit	Remark
Cylinder lubrication failure	Ref. Modbus List		From Reduce Word 2

Table 3.5-1 Main diesel engine alarm start parameters

To perform an alarm start the system requires that one or more DG is set in standby mode on the same switchboard or connected switchboard as the generator with the fault. If there is no standby DG on the same switchboard as the faulty generator, the system is not able to perform an alarm start of another DG.

3.6 Diesel Engine Alarm & Monitoring

For all details concerning main engine monitoring, please refer to instrument list and mimic layout drawings. All non important monitoring signals on the engines are interfaced by a Modbus serial line. All the important monitoring and control signals are hardwired.

Suppressed alarms when individual engines are not running:

AIM Tag	Description	Time delay	Signal type	Remarks
NIAHL-031113	Generator Frequency		RAIC1000_3	
EIAHL-031114	Generator Voltage		RAIC1000_3	
PIAL-011412	Engine X Fuel Oil Pressure	-	MODBUS	
PIAL-011201	Engine X Lub Oil Pressure	-	MODBUS	
PIAL-011501	HT CW BEFORE ENGINE	-	MODBUS	
TIAH-011707	Turbo Chrg Air A			
TIAH-011708	Turbo Chrg Air B			
PIAL-011503	LT CW BEFORE AIR COOLER			
TIAH-011202	LO INLET TEMP			
PIAL-011209	LO PRESSURE T/C INLET			

AIM Tag	Description	Time delay	Signal type	Remarks
PIAL-011201	LO INLET PRESSURE			
PIAL-011412	F.O INLET PRESS			

Table 3.6-1 Suppressed alarms when engines not running

All alarms are suppressed for 30 sec. or to gen. breaker is closed.

3.7 Cylinder Exhaust Gas Temperature Monitoring

The average exhaust gas temperature is calculated and each cylinder's deviation from the average is displayed. If the deviation exceeds the alarm limit as indicated in Figure 2-13 Exhaust Deviation Alarm Limit, deviation alarm is given. If the deviation exceeds the load down limit, engine load down / changeover is performed

The temperature calculation is done by Doosan Engine. The PMS receives temperature measurement fore each cylinder together with one digital alarm when the temperature reaches the alarm limit.

Alarm limit:

40 ^{o}C at 60-100% load (mean temperature > 450 ^{o}C)

70 ^{o}C at 15-59% load (mean temperature > 250 ^{o}C)

Alarms are suppressed when load is less than 15%.

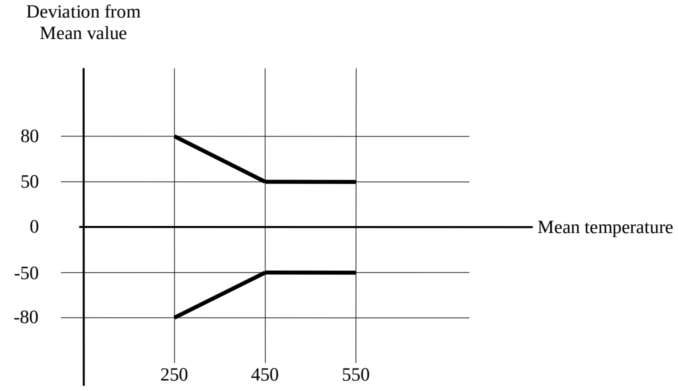


Figure 2-13 Exhaust Deviation Alarm Limit

Load down limit:

70 °C at full load (mean temperature > 450 °C)

100 °C at no load (mean temperature > 250 °C)

Engine load down is suppressed when mean temperature is less than 300 °C.

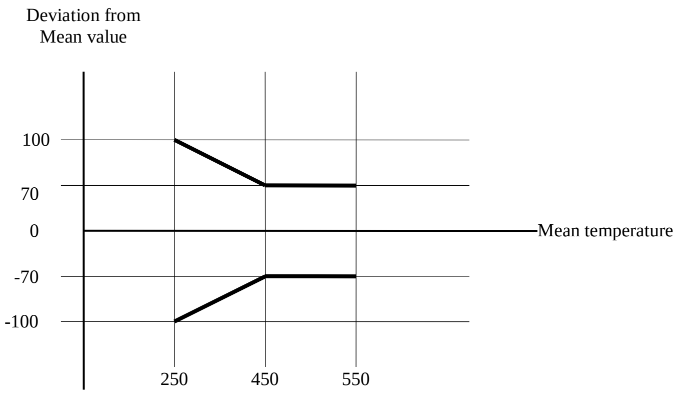


Figure 2-14 Exhaust Deviation Load Down Limit

3.8 Safety protection system

The safety system of the main diesel engines is divided in two groups:

- generator safety shutdown system
- generator change over system

3.9 Pre-lubrication

In order to ensure short engine start and connect time the pre-lubrication is continuous, i.e. the pre-lubrication pump will be automatically started by the engine (provided that the pump selected to auto mode in pump starter panel) when the engine has stopped. The pre-lubrication pump will automatically stop while the engine is running. While the engine is running the lubrication pressure is maintained by a mechanically attached oil pump.

3.10 HT and LT cooling water temp control

The HT cooling water temperature is controlled by dedicated temperature controller mounted on engine control cabinet and LT cooling water temperature is controlled by IAS.

3.11 Compressed Air System

Compressed air is used to start engines (Starting Air) and to provide actuating energy for safety and control devices. As a precaution the engine can not be started when turning gear is engaged.

3.12 Engine room fans

Engine room fans will be manually controlled from K-Chief. The different fans that were running before a blackout situation will be automatically restarted when the power is back.

3.13 Jacket preheating system

One pre heater unit is provided for each engine room serving two engines. The pre heater pump unit shall be run whenever diesel engine is stopped i.e. not run. This signal is energized whenever any engine is running below 100rpm. When both engines are running above 100 rpm, this signal is de-energized stopping the pump.

The jacket preheating system consists of a local panel with 4 heaters; the heaters can be selected from the selector switches located on the local panel. The selected heaters will be automatically switched on when the pre-heater pump is running. The pre heater pump runs when the engine is not running.

Pre heater units are controlled by engine local control panel and abnormal alarms (XA-017603/017613/017623) are interfaced to IAS.