Functional Design Specification

Thruster Control System

KM-Drill 8

Project:	12345678
Product:	Integrated Control & Monitoring System
Location:	
Synopsis:	This document descibes the scoope and functions of the Kongsberg Vessel Control system K-Chief as delivered to the specified vessel. This dokument when "as built" will serve also as operator manual together with KM standard K-Chief Operator Manual.

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1 About this document

1.1 Document history

Revision	*Description of Change*
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1.2 References

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1.3 Definitions / Abbreviations

AIM	Advanced Integrated Multifunction system
DNET	Dual Network
ECR	Engine Control Room
FS	Field Station (Cabinet with controller and/or RIO modules)
FU	Follow Up
IAS	Integrated Automation System (K-Chief)
ICS/ICMS	Integrated Control System / Integrated Control and Maintenance System
IO	Input / Output

ISO	Isolation (ISO amplifier)
K-Chief	Product name for KM IAS/ICS/ICMS
KM	Kongsberg Maritime
K-Thrust	Product name for KM RCS/TCS
LCL	Lever Communication Link
LU	Lube Oil
NA	Not Applicable
NDU	Network Distribution Unit
NFU	Non Follow Up
OS	Operator Station
PCK	Process Control Kernel
PMS	Power Management System
RBus	Remote IO Bus
RCS	Remote Control System
RCU	Remote Controller Unit
RI	Resistor current (Resistance to current converter)
RIO	Remote Input Output Unit

2 INTRODUCTION

2.1 Purpose

This document describes the scope and functions of the Kongsberg Maritime Integrated Automation System IAS, Thruster Control System (K-Thrust) as delivered to the specified vessel. Functions within other systems are not described in this document.

This document serves also as operator documentation together with KM standard operator manual.

The main topics in this document are:

- General Principles
- System Overview
- K-Thrust Functions
- K-Chief Extension

2.2 System Location

The K-THRUST consoles are located in forward Navigation Bridge and in DP backup room.

The K-THRUST Thruster Control Cabinets (Field Station) (6 ea.) are located close to the thruster drives.

2.3 General Information

The K-THRUST / KM Thruster Control System controls the speed and direction of the azimuth thrusters. Frequency converters are installed to control the thruster propeller speed. Each thruster and the corresponding frequency converter are interfaced to a dedicated process station (6 ea.).

Thruster commands are transmitted from the K-Pos or the K-THRUST console (whichever unit is in command) via the dual network to the thruster control Process Stations. Such commands are RPM, azimuth, start and stop orders.

2.4 K-THRUST Operator Station

The K-THRUST Operator Station contains the following equipment / functions:

- Three axis joystick controller
- Automatic heading control selection
- Wind compensation
- Azimuth thruster start/stop
- Individual control for each azimuth thruster
- Emergency stop push buttons for each thruster
- Command transfer system
- C-joy operator terminal
- Engine telegraph

3 K-THRUST400 THRUSTER CONTROL SYSTEM

3.1 General Principles of the Remote Control System

Each propulsion unit, steering gear or thruster has its own separate remote control system (RCS). A complete manual control system for a propulsion plant thus consists of a number of parallel RCS's. Common functions for command transfer and control mode selection at each control position synchronise the parallel systems.

In combination with other control systems, the RCS acts as the "owner" of the propulsion/ thruster. It controls command access to the equipment and ensures that transitions between control systems takes place in a safe manner. The RCS sees no fundamental difference between a control system from KM and from other vendors, although the integration with KM systems provides a more unified overall control system.

As a consequence of individual RCS systems for each equipment unit, control systems that require access to more than one unit are interfaced to the RCS systems of each of the applicable units. KM systems (like K-Pos or Joystick) can do this via a LAN connection, while control systems from other vendors have to use serial connections or discrete wiring. For installations where DP class requirements shall be met, it is essential that manual thruster commands from the RCS system and commands from the DP control system use different communication links.

3.1.1 Thruster Controller Software Platform

The RCS controller application is based on AIM software. The runtime application for each propulsion unit, steering gear or thruster is stored in dedicated servers (K-Chief OS).

3.1.2 Communication Links

The RCS controllers communicate with the Maintenance Station and other KM operator stations and controllers via local area network. The communication between the RCS lever panels and the RCS controller is handled by a Kongsberg proprietary bus system (RBUS), the bus system is identical to the communication link between the RCS controller and RIO units. In the K-Thrust - RCS context, the RBUS connection to lever panels is referred to as the Lever Communication Link (LCL).

3.1.3 Lever Panel IO Principle

The RCS controller considers the RCS lever panels as generic IO, supported by AIM / PCK IO system. This implies that the RBUS is used as an IO bus and the panels are considered as remote IO units with some panel-specific capabilities. With this principle, the RCS control application is independent of the physical IO connection. The SW and the configuration parameters that define the control capabilities are located in the RCS controller.

3.2 RCS Main Tasks

The main functions available in the RCS controller can be summarized as follows:

- Handle connected levers and lever panels and respond to operator action.
- Handle command transfer between alternative control positions.
- Handle control system selection of the different connected control systems (e.g. Lever control, DP control system, Independent Joystick control system, external Autopilot).
- Handle Synchronous Control between two or more propulsion units, steering gears or thrusters.
- Handle bumpless transfer between control positions and to Lever control from other control systems.
- Execute start and stop sequences.
- Execute closed servo loops.
- Execute load reduction.
- Handle field IO.

4 System Overview

K-THRUST Layout of manual levers are located in the thruster controller**:**

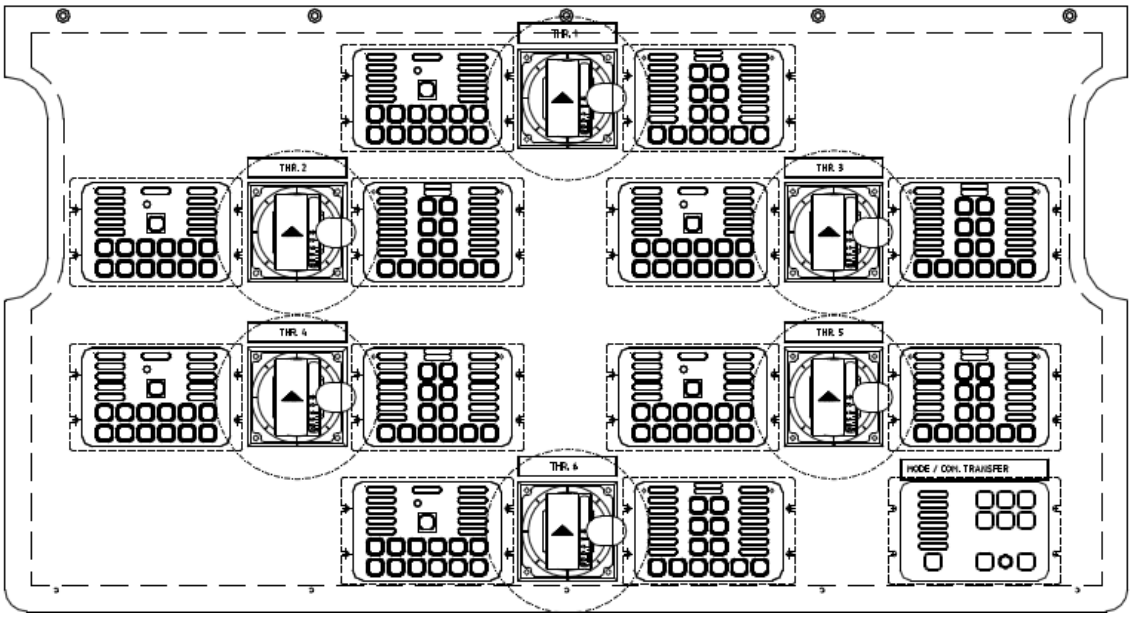


Figure 1 – Horizontal Layout

K-THRUST Layout of indicators:

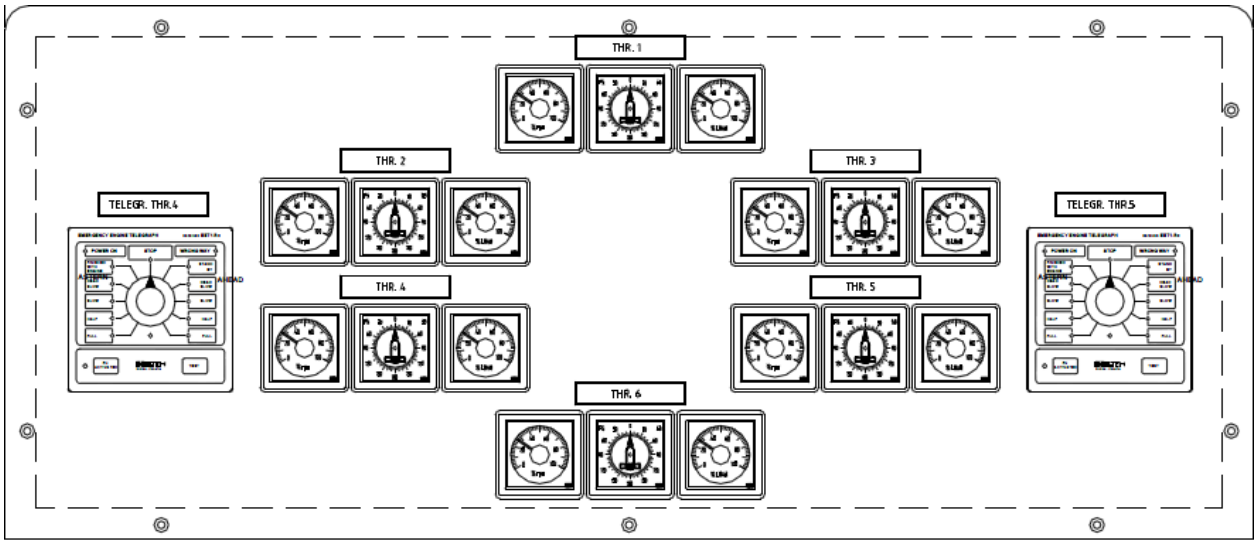


Figure 2 – Vertical Layout

4.1 RCS Controllers

The basis of the K-Thrust system is that each thruster has its own dedicated RCS controller. The RCS controller consists of one (two if redundant) Remote Control Unit (RCU) and a required number of Remote IO (RIO) units for handling field IO. The RCS controllers are connected to each other via LAN.

4.1.1 Location of RCS Controller Cabinets

Thrusters and Field Stations Location:

Cabinet ID	Controller Type	Location	Remark
FS201	RCU502	Centre forward	Thruster 1
FS202	RCU502	Port side forward	Thruster 2
FS203	RCU502	Stbd side forward	Thruster 3
FS204	RCU502	Port side Aft	Thruster 4
FS205	RCU502	Stbd side aft	Thruster 5
FS206	RCU502	Centre aft	Thruster 6

4.2 System Start/ Restart

When started, panel controllers will display the state received from its thruster controller.

When a thruster controller is started, its system state is defined by

- The Thruster Control mode (DP or Manual)
- Operator station in command

The thruster mode will be set to a default initial state at start up. If the thruster controller is connected to the LAN, the RCS mode and the operator station in command can be found from thruster controllers already running. If no such information is available, the thruster controller will depend on operator assistance to establish RCS mode and operator station in command. Thrusters requesting such support will indicate this by flashing the alternative panel buttons.

If the RCS mode at system start-up involves manual command from a lever, this lever will not be given command unless the lever deflection corresponds to the "neutral" start-up command (zero force). If necessary, bump less transfer guidance will be activated.

A lever position different from zero force may be an inhibit condition for starting the thruster drive, and by that ensure that the thruster lever must be in a controlled position before the thruster becomes running.

The RCS will not send out a "ready for command" signal before a control station and a thruster control mode have been selected in the system

4.3 Command Positions

The RCS system can be operable from different control positions.

This delivery has the following setup:

Position name / Location	***Controllable thrusters / rudders***	***Functions***	***Additional equipment***
Wheelhouse	Thr 1, 2, 3, 4, 5, 6.	Start/Stop, Mode selection, Synch control,	Utility panel, Indicators, Steering Wheel

DP Backup room	Thr 1, 2, 3, 4, 5, 6.	Start/Stop, Mode selection, Synch control,	Utility panel, Indicators…

4.4 Bridge Panels

The lever and utility panels are the user interface devices for the RCS controller. Each lever panel within a control position communicates the states and commands for one thruster / propulsion unit. The utility panel is common for all thruster / propulsion units.

From a fully configured panel, it is possible to

- Give manual thrust commands from a lever
- Change thruster control mode
- Monitor RCS state
- Monitor equipment feedback (RPM, Azimuth angle, Power)
- Emergency stop the main mover
- Lock the thruster to lever

Colours on status lamps and buttons are used to amplify the significance of the button/lamp:

- *Green lamp*: Normal state (e.g. function selected / status)
- *Red lamp*: Abnormal state (e.g. shutdown / alarm)
- *Yellow lamp*: State of caution (e.g. power limit)
- *Blue lamp*: Command position (e.g. FORWARD)
- *Double push button*: White text on a dark background with a white bar across the bottom.
- *Single push button*: White text on a dark background.

Flashing status lamps indicate conditions that may require operator attention.

4.4.1 Utility panel

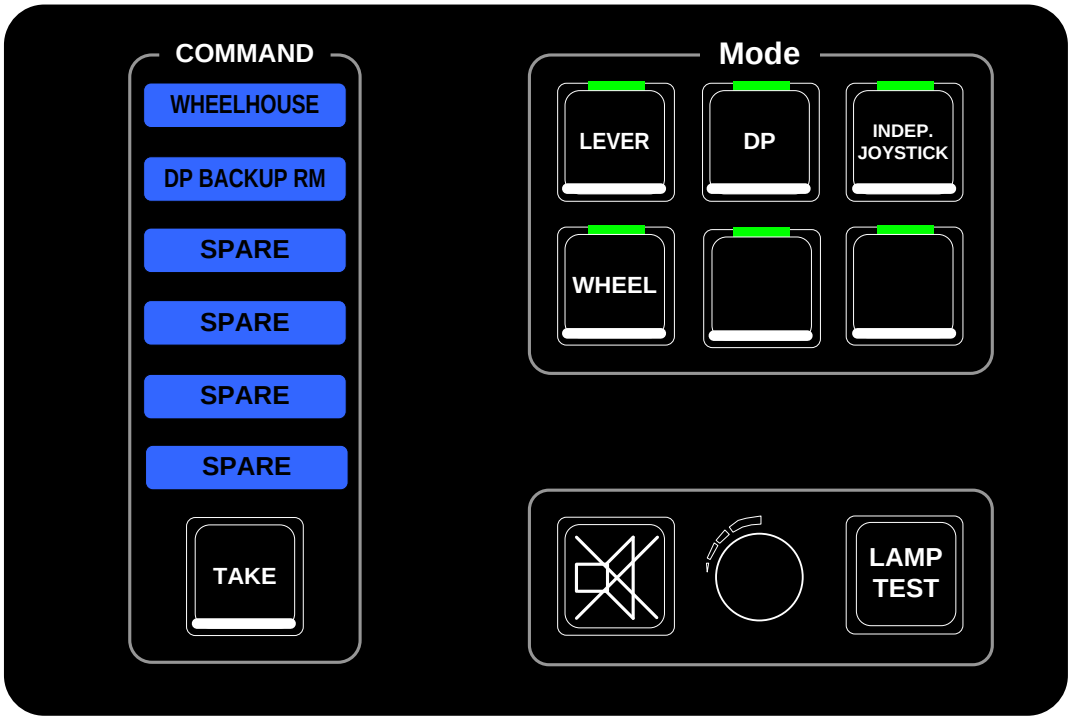


Figure 3 - Utility Panel (Illustrated picture)

The utility panel is the user interface for functions common to more than one RCS controller. The panels are installed in control positions with lever panels for more than one thruster unit, and provide the following functions:

- Command transfer between alternative bridge control positions
- System mode selection
- Buzzer silence
- Lamp test
- Light level dimmer

Utility panels are regarded as extensions to each lever panel. Lamps and buttons of the utility panel are wired to each panel controller (RPC) as shown in Figure 4.

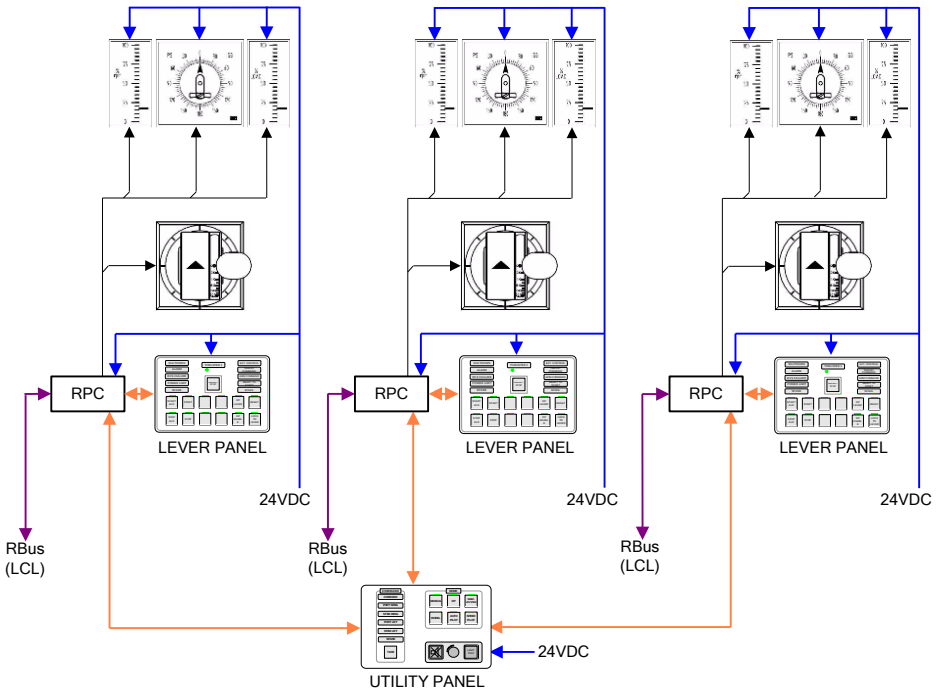


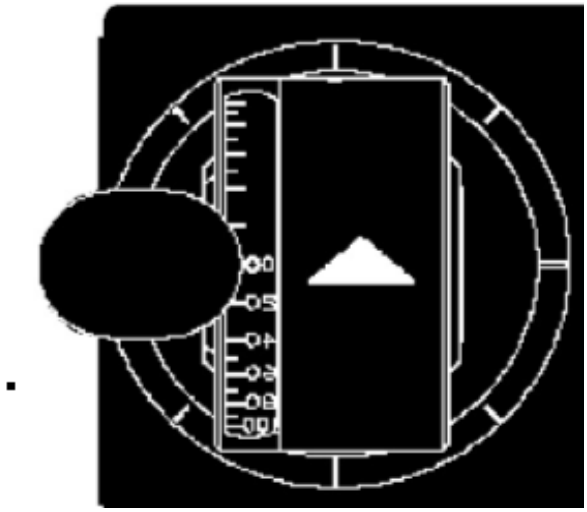
Figure 4 - Internal signal wiring in an RCS control position (example configuration)

4.4.2 Centralized Dimmer and Buzzer Silence

A panel dimmer potentiometer is part of the utility panel. Through the dimmer circuits of the panel controller, this potentiometer can be used to dim the backlight of the utility panel and all lever panels, levers and instruments, and direct wiring panels within the control position.

All lever panels have their own dedicated buzzer to report audibly when needed for that specific thruster/rudder. However, the silence function is centralized with one button on the utility panel silencing all buzzers within the control position. The station in command will also be able to silence alarms from other command locations.

4.4.3 Lever Panel, Thruster 1



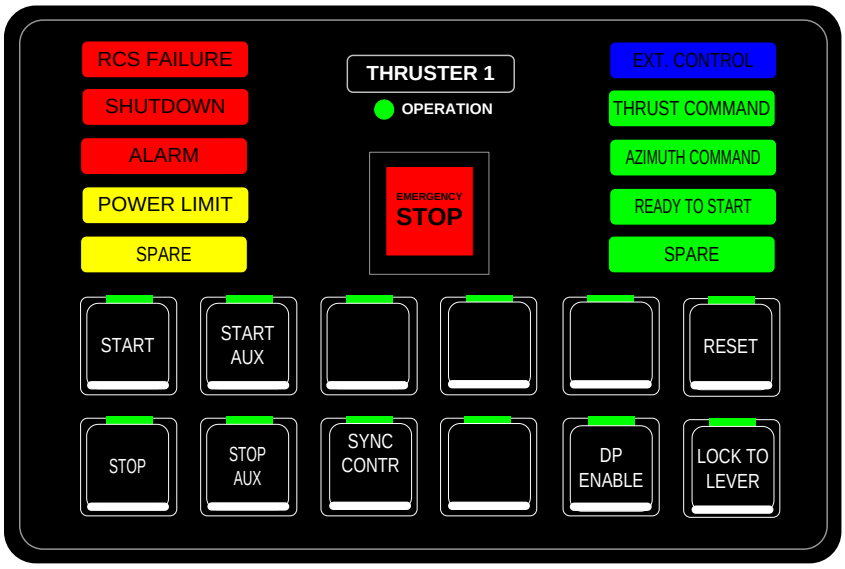


Figure 5 – Lever Panel

Lever:

- Azimuth lever - Give manual thruster follow up (FU) commands

Buttons with green status lamps:

- START – Start thruster prime mover
- STOP – Stop thruster prime mover
- START AUX – Start azimuth steering gear
- STOP AUX – Stop azimuth steering gear
- DP LEVER - Lock command control to the manual with bumbles transfer
- DP ENABLE – Enable thruster for DP control
- RESET – Acknowledge thruster alarms (see chap. XX for details)
- SYNCH. GROUP – Synchronous command function
- LOCK TO LEVER – Lock command control to the manual lever (overrides the common selection from utility panel)
- RESET – Resets all alarms for this thruster

Emergency stop button (red) with protective cover and status lamp:

- EMERG. STOP - Emergency stop the prime mover

This function is independent of the K-Thrust system and the button is hardwired directly to the thruster drive.

Lamps:

- RCS FAILURE (Red) – Internal RCS failure detected (e.g. IO failure, power failure)
- SHUTDOWN (Red) – Thruster tripped
- ALARM (Red) – Thruster in an abnormal state
- POWER LIMIT (Yellow) – Load reduction active from drive or PMS
- EXT. CONTROL (Blue) – Thruster controlled by external system
- THRUST COMMAND (Green) – Thrust can now be controlled by this lever
- AZIMUTH COMMAND (Green) – Azimuth angle can now be controlled by this lever
- READY TO START (Green) – Thruster is ready to be started

Indicators connected:

- RPM, Azimuth, Load

4.5 Mode Selection

The thruster control mode selection buttons is located in the utility panel on each Control station, as seen in figure 3.4. Light in the buttons will give information about the active mode. The choice of system mode determines whether the RCS will read the thruster command from lever, DP controller or the independent joystick controller.

The Thruster Control Mode selection will be available on both Control stations. Only one thruster control mode can be selected for all thrusters, and each position will only have possibilities to select the system modes that can be controlled from that command position.

4.5.1 NFU Panel

The NFU panel is hardwired to the propulsion and steering gear systems.

There are total six (6) NFU Panel, one for each thruster located in the Wheelhouse.

The K-Thrust console in DP Backup room don't have this function.

Functions:

- Lamp test for NFU panel
- Silence for NFU alarms
- Dimmer for NFU panel is provided from the Utility panel

- **ABB:**

	Signal type
DRIVE TAKE	DO
RPM INC	DO
RPM DEC	DO
DRIVE IN COMMAND	DI
DRIVE READY	DI
DRIVE ALARM	DI

- **WARTSILA:**

THR TAKE	DO

AZI CW	DO
AZI CCW	DO
THR IN COMMAND	DI
THR READY	DI
THR ALARM	DI
PWR FAIL	DI
STEERING PUMPS ABNORMAL	DI

The K-Thrust system reads the NFU status from the propulsion unit / steering gear system. Activation of NFU mode is indicated by a flashing “EXT. CONTROL” lamp together with an audible alarm. Pressing silence will cease the audible alarm and the EXT. CONTROL lamp will be steady lit. Returning back to normal mode will initiate the same indication.

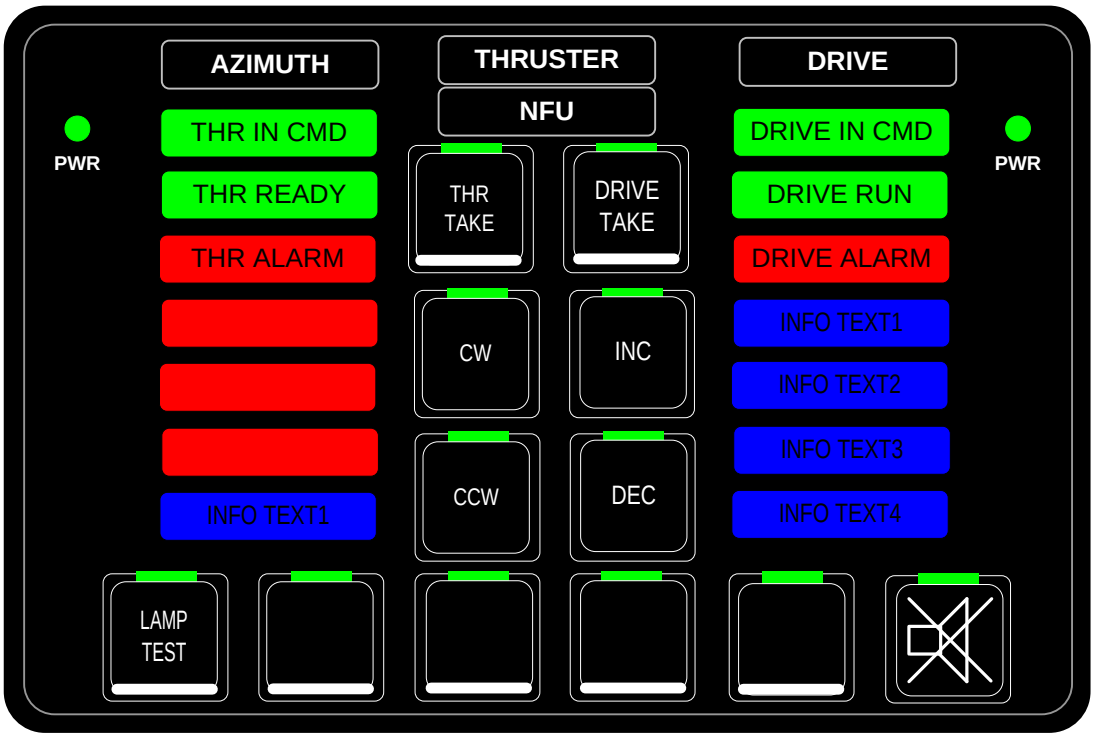


Figure 6 NFU panel.

4.6 Indicators

All the indicators are connected to the RCS panel controllers and fed with feedback information from the RCS controllers. However, there are some indicators which are directly wired to the feedback potentiometers on the thrusters.

For this vessel the overhead indicators are directly wired to the feedback potentiometers. RI converters and ISO amplifiers are used.

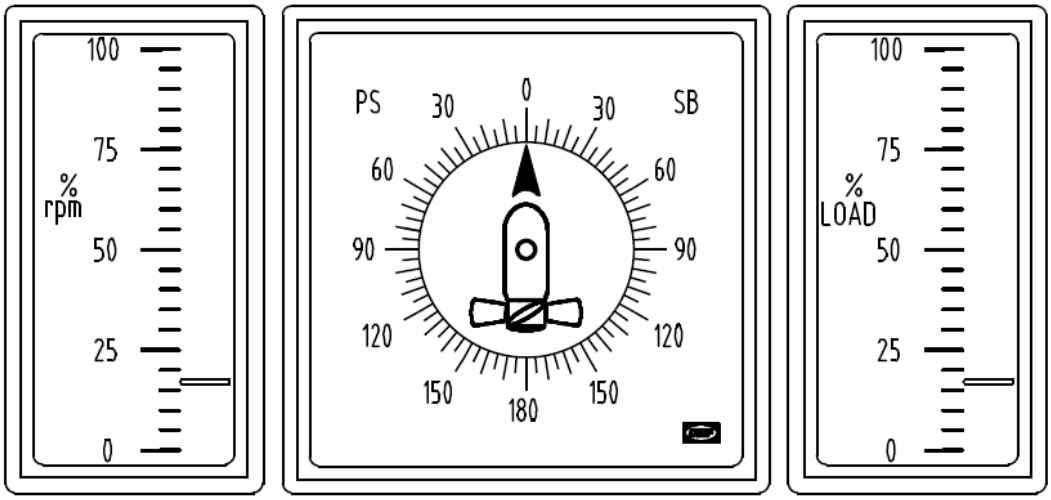


Figure 7 - Indicators

4.7 Local Control

Thrusters can be controlled from two local positions. First there is a local panel (LCP) on the Kongsberg thruster control cabinet, which act as an IAS extension panel which control both thrust and azimuth. Furthermore, both the drive and the azimuth can be controlled locally from the ABB drive and from the Wartsila azimuth.

4.7.1 KM Local Control Panel

Local control panels are located in the thruster controller cabinet door.

By switching to Local Control Mode on the LCP, the thruster will be controlled from the LCP.

The functions of the panel are similar as for the lever panels, with the following exceptions:

- The thruster is controlled by Increase/ Decrease and Clockwise/ Counter clockwise command buttons
- Local / Remote command changeover switch

This panel works as a pseudo NFU panel, as the increase / decrease and clockwise / counter clockwise switches will not act directly on the equipment, but increment / decrement the commands going into the thruster servo control loop.

.**Thruster Local Control panel layout**

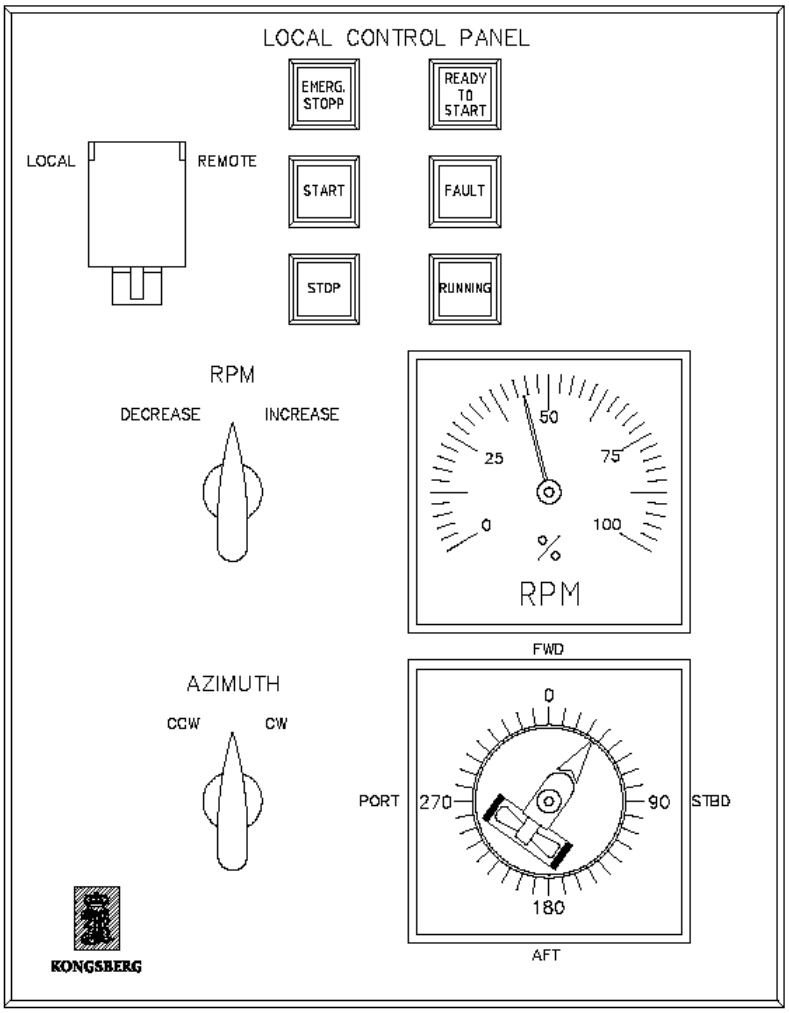


Figure 8 – LCP layout

Note: The **Emergency Stop** signals are hardwired directly to the thruster drive.

Interfaced to the Local Control Panel

Thruster Local Control Panel Alarm and Status Monitoring signals:

AIM-Tag	Description	Remarks

XC-021131	Ready to Start	Green Light
XC-021133	Running	Green Light
XC-021132	Failure	Red Light, Common Failure
NY-021131	Speed Feed back	+/- 100 % speed indication. The indication will switch to speed set point indication when speed decrease or increase commands are active.
NY-021132-A NY-021132-B	Azimuth Feedback (sin) (cos)	0-360 deg angle indication. The indication will switch to azimuth set point indication when azimuth CW or CCW command is active.

Thruster Local Control Panel signals:

AIM-Tag	Description	Remarks
XI-021133	Remote Control Mode	Switch, with flip over cover
XI-021131	Start	Push Button
XI-021132	Stop	Push Button
N/A	Emergency Stop	Push Button with cover, Hardwired directly to thruster drive.
XI-021134	Speed Increase Command	Will ramp the speed set point to 100
XI-021135	Speed Decrease Command	Will ramp the speed set point to 0
XI-021136	Azimuth CW Command	Will ramp the azimuth angle set point CW
XI-021137	Azimuth CCW Command	Will ramp the azimuth angle set point CCW

4.7.2 Command Transfer to a Local Panel

Command transfer to a local panel is by taking the command at the panel. This is possible independently of the current RCS mode.

The “Ext Ctrl” lamp on the K-Thrust lever panel will be lit when this mode is active as this pseudo NFU backup control acts as a local controller.

4.7.3 Local Start and Stop

It will be possible to start and stop the thruster from the local panel when command is taken at the panel. The start /stop signal will trig the same sequence as when start /stop are pressed on the bridge lever panels (ref. start /stop sequences).

4.7.4 Thruster Local Control

Azimuth local control: The thruster azimuth has a local/remote switch. When this is in local position the thruster steering can be controlled by manually operating the solenoid valves in the hydraulic circuit. This operation can be done from the front facia of the azimuth control unit. Hydraulic pumps shall be running for this local control.

Drive local control: The thruster drive has a local/remote switch. The thruster RPM can be controlled locally from the ABB Drive panel when the converter is switched to local mode.

4.7.5 Indication

When a thruster/propulsion unit is taken in local control, a “Local Ctrl” status lamp on the corresponding RCS lever panel(s) will start flashing together with an audible indication.

4.8 Thruster RCS View on DP OS

The “Thruster RCS view” is available at all K-Thrust The view is adapted to the orientation of the OS, and the view shown below is for the “Main Forward” K-Thrust OS.

The figure used is just an example and does not match the rest of the configuration described in this document.

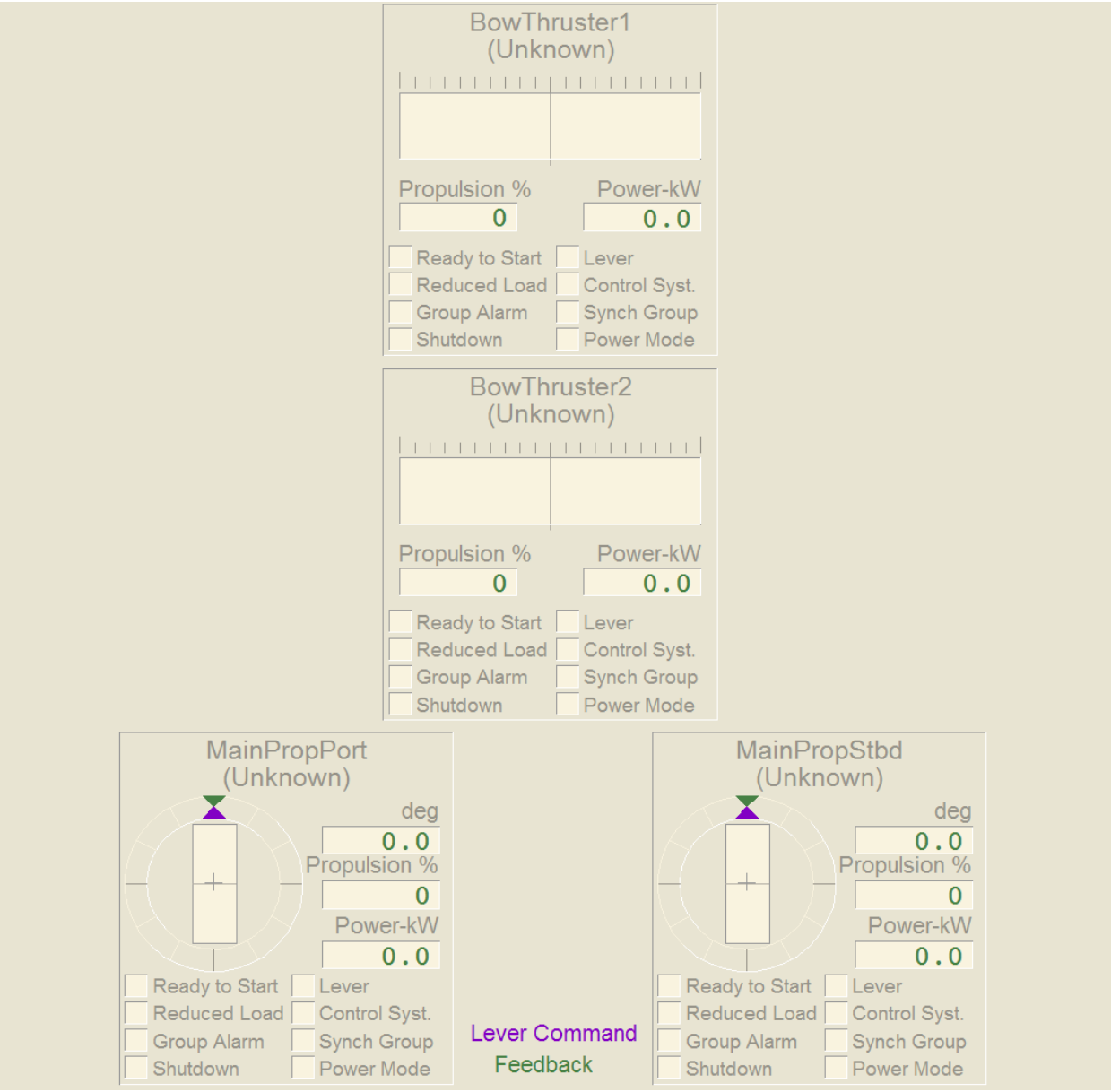


Figure 9 Thruster RCS View

5 RCS Functions

5.1 Supported RCS System Modes

The RCS supports the following modes.

LEVER	**:**	In this mode the control is by manual levers. When the mode is enabled the LEVER status lamp is lit. The thrust control is on the lever when the "Thrust Command" status lamp is steadily lit and azimuth control when the "Azimuth Command" lamp is steadily lit. In case of one of these status lamps flashing, the bumpless function is active or there is failure in lever signal.
DP	**:**	The RCS controllers are set up to read all thruster force and direction commands from the DP control system. Other command privileges remain within the RCS, except start/stop of thruster/propulsion which can be shared with the DP control system. Note that the DP system can have internal Autopilot function and when enabled the thrust command will be on the lever when the green "Thrust command" lamp is lit.
INDEP. JOYSTICK	**:**	The RCS controllers are set up to read all thruster force and direction commands from the Independent Joystick System. Other command privileges remain within the RCS.
DP AUTOPILOT	**:**	The RCS controllers are set up to read steering commands from the DP Autopilot. Thruster force (RPM will be set manually from RCS . The autopilot is selected on the DP.
WHEEL	**:**	The RCS controllers are set up to read steering commands from the Wheel. Thruster force (RPM must be set manually from RCS levers.

NOTE: Only LEVER, DP mode and Independent Joystick is available on the utility panel for this vessel. DP Autopilot mode is set in DP system.

5.2 Bumpless Transfer

To ensure that command transfer from one RCS control position to another takes place without significant change of thrust, the lever positions in the gaining position has to match the commands from the levers in the giving position. The last command from the giving station will be retained until the lever position is within predefined limits.

The function is applicable in all thruster control modes involving commands from levers in manual mode.

It also applies when a lever is suspended from synch control and for the new master when changing master during synch control. These transitions take place within the same control position and imply that a lever leaving the synch group has to be adjusted if it deviates from the master lever.

Thrusters entering LOCK TO LEVER mode (by pressing this button on each lever) will suspend any active bumpless state for the actual thruster.

Both the azimuth command and the thrust command must be matched. The operator will be warned that command matching is required by indication on the lever panel. (Flashing command lamps "AZIMUTH COMMAND" and "THRUST COMMAND"). If the lever command is not aligned within 10 sec, an audible alarm will be activated.

The function has no control input from the user, but has the following configuration parameters:

- +/-15% for azimuth
- +/-15% for thruster rpm
- Deactivate function for transfer between RCS positions
- Deactivate function for change of system mode into Manual mode

The table below shows this vessels configuration of the bumpless function.

Bumpless function:	*Active:*	*Remark:*
Transfer of command between control positions on the wheelhouse and in the DP backup room	YES	
Transfer of command control from DP, Joystick to Lever control	YES	
Changing group master when the Synchronous command function is enabled	YES	These two are covered by the same parameter in SW. Both are

Disabling the Synchronous command function	YES	either active or disabled.
Changing from Steering wheel control to Lever control	YES	
Towards zero when thruster start	YES	

5.3 Emergency stop

Each lever panel on the bridge will be equipped with emergency stop buttons. These buttons will be external to the RCS system, and hardwired to the thrusters.

5.3.1 Principles

RCS system mode is, by design, individual to each equipment unit. In systems with multiple units, RCS mode selections are common to all units. The main principle is that equipment speed (RPM or pitch) and azimuth command can be given away, while the remaining privileges (e.g. functions selected from the lever panel buttons) stay with the RCS and are accessible at the RCS position in command.

5.3.2 General RCS mode Changeover Restrictions

The following restrictions apply when changing control modes:

- All RCS lever panels with independent control systems have a “Lock Manual” function. All command privileges for the thruster will be taken by the RCS system when this function is activated. The lock is stronger than Manual mode alone, as it will also prevent the thruster from being slaved to a group master.
- In this state the controller continue sensing the position of the thruster control mode selector and once the lock lever button is released the control mode for the unit will change accordingly. This function is enabled individually for each thruster, and it can only be enabled on the RCS panel in command of the RCS system.
- In configurations with individual control systems, it is possible to force the RCS to change mode when transferring command to a specific command position. This transfer can either be automatic or manual. When automatic, the mode changes to a predefined mode for that position. When manual, the new station will prompt for mode change by flashing with selectable mode buttons. If a legal mode has not been selected within a timeout time, the transfer will not take place.

5.4 Rudder and Crash Stop Limits

Maximum rudder angle and angle for crash stop activation in Autopilot mode are configured specifically for each vessel. The table below shows this vessel's configuration for Azimuth thruster and Crash Stop limits.

To do a crash stop, the operator turns levers more than 60% off previous azimuth angle and set full thrust.

To get back to operation you turn levers back within 45° off command before crash stop operation was detected.

Thruster/Rudder:	*Rudder limit:*	*Crash stop limit:*	*Wheeloverride limit:*	*Remark:*
Thruster 4, 5	+/- 45 deg	+/- 60 deg	+/- 15 deg	

5.5 Synchronous Command Function

The available thrusters can be grouped so that all the thrusters that are members of a group can be controlled simultaneously by a single (group master) lever.

When the Synchronous command function is active, the master lever for a group can be changed at any time by the SYNCH. GROUP button.

If configured, a bumpless transfer of command control is automatically activated when changing the group master lever from the master lever panel to a slave lever panel, and when disabling the Synchronous command function.

Synch Group	*Thruster Members*	*Remark*
Synch Group I	1,2,3,6	Sync contr |
Synch Group II	4,5	Sync contr ||

In transit mode, Thrusters in group I act as propulsion thrusters, and thrusters in group II act as steering thrusters. When selecting the “Synch cmd” button on one of the lever panels, the thrusters within its group will be controlled by the lever selection command was set from. Within the synch group bumpless operation rules apply.

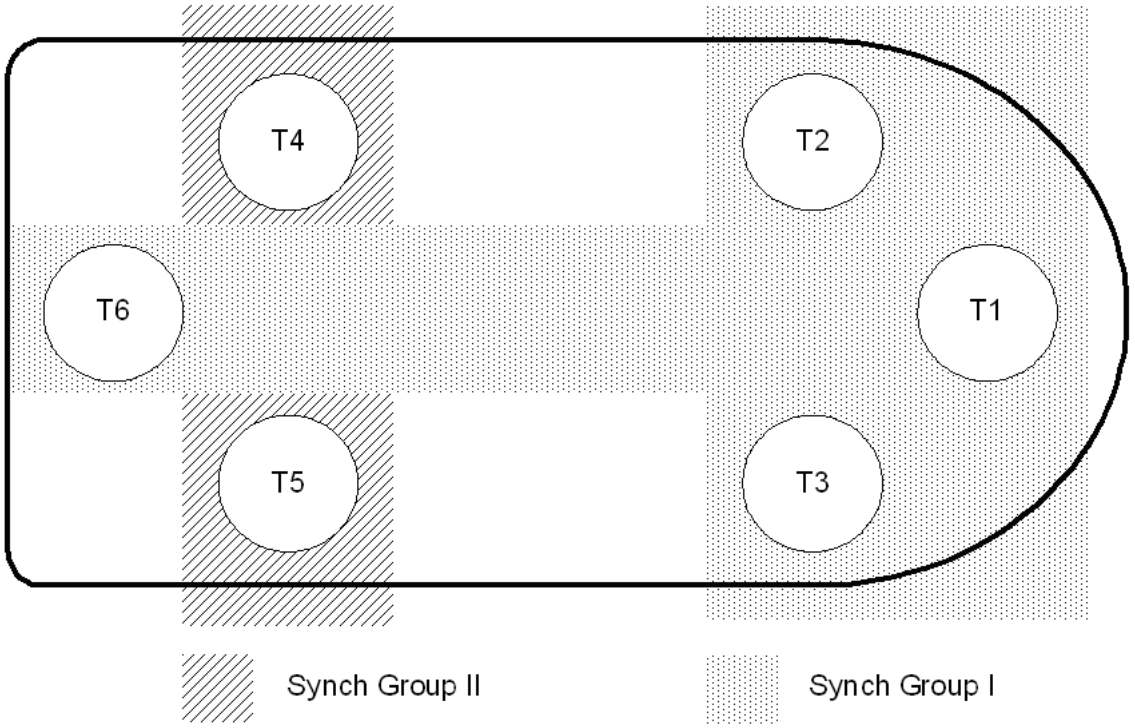


Figure 10 Synch Groups

5.6 Lock to Lever

When pressed, the LOCK TO LEVER button (double push within 0,5 sec.) will give both azimuth and thrust command privileges to the lever where the button was pressed. Note! The control position must be in command of the thruster for the button to work. Hence, a thruster can be controlled from the lever, even if DP is selected as overall thruster control mode. Deselecting the LOCK TO LEVER button will make the thruster follow the main thruster control mode again, i.e. DP.

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5.7 Alarm Indication

5.7.1 Alarm System (K-Chief)

Each RCS controller is interfaced to the K-Chief which is the Alarm System. All required alarms will be sent to this system and displayed there.

The interface between K-Chief and Thruster equipment is by serial line or hardwired. Reference is made to the IO list.

5.7.2 Alarm System (DP)

Each RCS controller is connected to a KM Operator station via LAN. All internal RCS alarms will be sent to this station and displayed on the alarm page.

5.7.3 RCS (K-Thrust) Lever Panel

There are three lamps on each RCS lever panel used for alarms and failures in the system.

- RCS Failure lamp
- Shutdown lamp
- Alarm lamp

RCS Failure lamp – The "RCS Failure" lamp is used for visual indication of an abnormal state in the RCS system. This will be given together with an audible indication, which must be silenced from the Silence button on the utility panel.

The "RCS Failure" lamp will flash as long as there are unacknowledged alarms in the system, and be steadily lit if all alarms are acknowledged, but the system still in an abnormal state. To find out which system failure that has been detected, the operator must use the message view on a connected KM operator station.

Shutdown lamp - The "Shutdown" lamp is used for thruster tripped conditions. The lamp will be flashing and an audible alarm activated when the thruster has tripped. The silence button must be pressed to silence the alarm and a steady lit alarm lamp. The lamp condition is controlled by an external signal given from the thruster, and a reset of the alarm must be done on the respective control system.

The RESET button may be used to reset the drive after a Shutdown, provided that the fault has been examined by qualified personnel.

Alarm lamp – The “Alarm” lamp is used to indicate that the propulsion unit has an active alarm state. The lamp will be flashing and an audible alarm activated when an alarm becomes active. The silence button must be pressed to silence the alarm and a steady lit alarm lamp. The lamp condition is controlled by an external signal given from the thruster, and a reset of the alarm must be done on the respective control system.

The RESET button may be used to reset the drive for some alarm instances, provided that the alarm has been investigated by qualified personnel.

6 K-Chief

The K-Chief and K-Thrust systems are integrated. The K-Chief acts as an extension of the K-Thrust system and enables detailed monitoring and extensive control possibilities.

The K-Chief/K-Thrust system contains the following control tasks:

- Start Sequence
- Stop Sequence
- Speed Setting
- Speed Mode
- Azimuth Setting
- Load Limitation
- Alarm Monitoring
- Auxiliaries Control
- Fail-safe Consideration

6.1 Thruster Data

The azimuth thruster is speed controlled by the variable frequency drive and electric motor, and has a fixed pitch propeller. This thruster can only be operated in positive direction. (Normal operation in 0-100%).

6.1.1 RPM Setting

The speed setting is performed from the K-Pos/K-THRUST system if the thruster plant is selected to K-Pos/K-THRUST Control.

When the thruster plant is selected to K-Pos/K-THRUST Control the speed reference is routed via the network to the K-CHIEF process station.

The speed reference is controllable from 0% to 100% (0RPM to 600 RPM). The reference is defined by a 4 - 20mA analogue output signal where 4mA corresponds to 0 % and 20mA to maximum rotation 100%. (The thrusters motor has a maximum speed of 750 rpm). The speed (RPM) feedback signal is a 4 - 20mA signal (NI-021111) where 4mA corresponds to 0RPM and 20mA + 720RPM. K-CHIEF system will generate an out of range alarm if difference between reference and feedback is > 6.25%.

A dead band is applied in the ACS-6000 Control Unit. The converter modulation will start when speed reference is > +/- 36 RPM. To avoid rpm mismatch alarm caused either by the dead band in the ACS-6000 Control Unit or by the wind milling effect the feedback will be "manipulated" during first 50 seconds. The feedback will be set as the same as that of the set point value. The timer value (50 seconds) is set in accordance with the timer value for checking of the rpm mismatch (60 seconds).

6.1.2 Azimuth Control Loop

The azimuth control loop is integrated in the K-CHIEF system for total control and failure handling capabilities of the thruster azimuth steering system.

The azimuth rotation setting is performed either from the K-Pos/K-THRUST system if the thruster plant is selected to K-Pos/K-THRUST Control, or from the K-CHIEF operator station if the thruster plant is selected to Service Mode. The azimuth rotation setting is routed via the network to the K-CHIEF process station. The azimuth reference rotational direction is controllable from +180deg to -180deg.

The reference (XC-021143) is defined by a 4 – 20 mA analogue output signal to the valve actuator unit, where 12mA corresponds to zero degrees, 20mA to +180 degrees and 4mA to -180 degrees. The K-Chief process stations supplies 24Vdc to the actuator units.

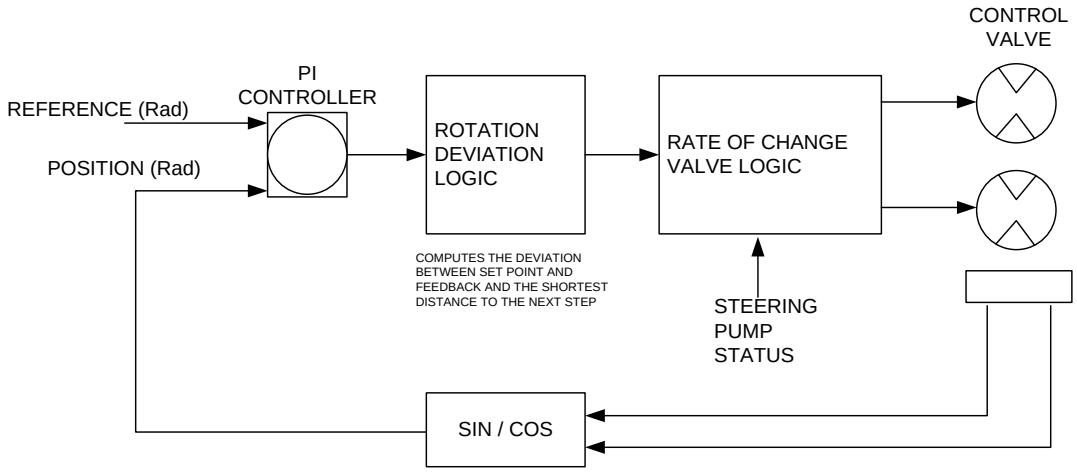
There are two steering control valves. When steering pump is stopped the control signal is set to zero.

Local / remote selection of the Wartsila control unit is provided (XI-021126). When in local, the thruster will be deselected from K-Pos operation.

The following signals will enable the Azimut in Remote control.

Seq	*Tag*	*Description*	*Sig Type*	*Remark:*
1	XI-021124	Remote Selected (Request)	DI	L/R Changeover set to remote
2	XC-021141	Remote Accepted	DO	The Remote Selected Input sent as output

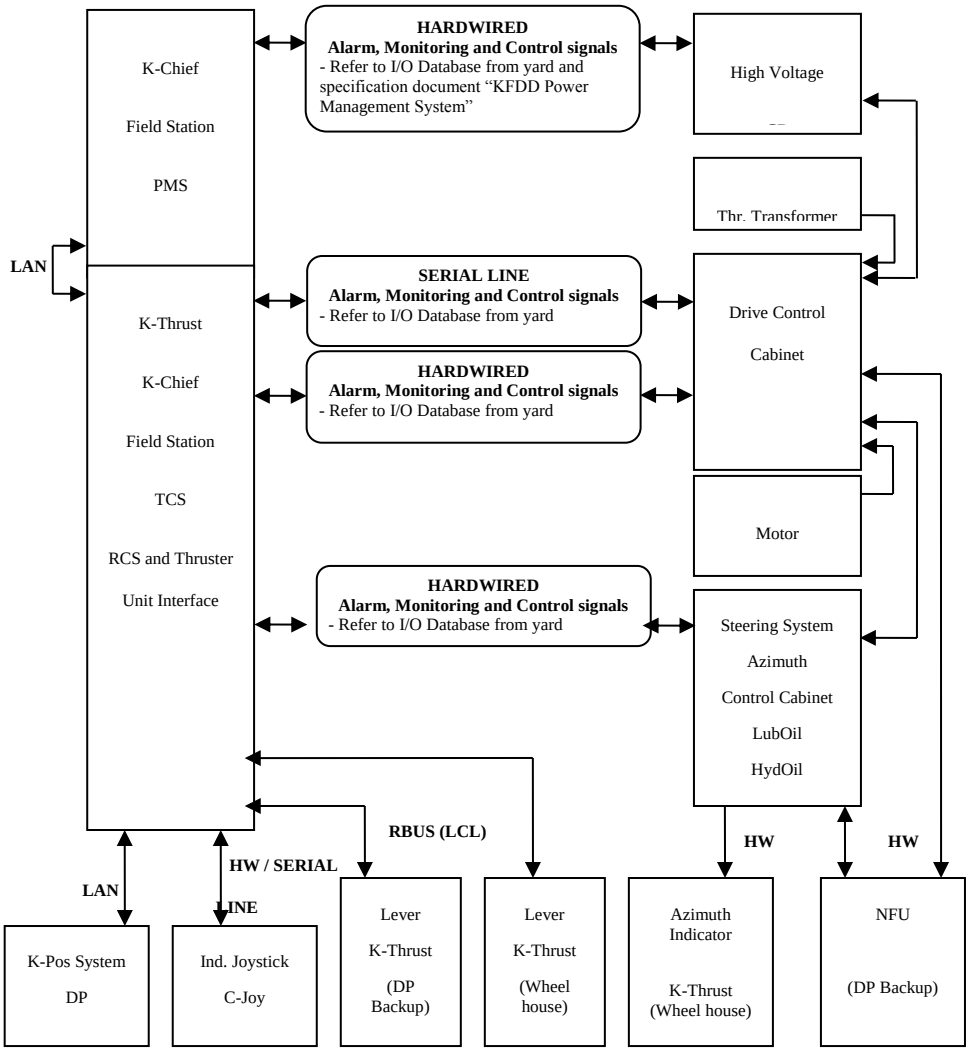
3	XI-021126	Remote in Service	DI	Remote control enables/Used as master remote signal



The azimuth feedback signals are provided by triangular potentiometers mounted directly on the thrusters. The azimuth feedback signals are +/- 10VDC signals where 0V corresponds to zero degrees, +10V to +180 degrees and -10V to -180 degrees. The azimuth feed back is provided in 2 channels, one directly connected to the K-THRUST station and the other to the thrusters control process station for DP. The K-CHIEF process stations supplies +/- 10Vdc to the steering feedback potentiometers. K-CHIEF process station converts the received +/- 10VDC signal to 4-20 mA signal.

Thruster K-CHIEF servo loop

6.2 Thruster Control System Overview



6.3 Thruster Start/Stop

The Start/Stop of the thruster drives can be activated from the RCS Lever panels.

A Start/Stop command will activate the start/stop sequence. In order to obtain successful start/stop the corresponding equipment must be in remote/auto mode and functioning.

If a timeout occurs an alarm is given on the K-Chief system and the sequence will halt / terminate. The reset lamp together with the start or stop status lamp will start flashing rapidly. A reset by the sequence administrator is then necessary, by double pressing the reset button.

The sequence administrator module will be visible in the K-Chief specific thruster mimic. It will indicate the status of any sequence and any step.

The following equipments are controlled by the sequences:

- Drive
- Hydraulic Steering Pumps
- Lube Oil Pumps
- FW Cooling Pumps
- SW Pumps
- Drive Cooling Fan
- Thruster Transformer Cooling Fan

The rpm setpoint from K-Chief is set to Zero during the start/stop sequences.

The reset button will terminate any start or stop sequence, and send a reset to the drive.

6.3.1 Thruster Start Sequence

The Start sequence can be activated from the lever panel by a double press at the START button, when the "Ready to Start" lamp is lit. In order for the "Ready to Start" lamp to be lit, no start interlock must be present and the lever rpm axis set to zero.

If a timeout occurs (see table below) during the start sequence, an alarm is given on the K-Chief/K-Thrust system.

The START lamp will start flashing while the sequence is active.

Thruster start sequence:

Step	Action	Condition for next step	Timeout	Remark
1	Hydraulic pump in Auto Lubrication pump in Auto Transformer fans in Auto Thruster motor fan in Auto Drive in Auto		30s	Setting auxiliaries in auto prior to start
2	Start transformer fans Start thruster motor fan Start CSW pump and FWC pump if not already running	Min. one Cooling fan running Motor Cooling fan running Min. one FWC pump running Min. one CSW pump running	30s	Starting cooling systems Start CSW pump and FWC pump if not already running
3	Start lubrication pump Start hydraulic pump	Lub. Oil Pump running Hyd. Pump running DCU ready to start	30s	
4	Activating Drive	MainDrive running	180s	The Drive will start
End				The START button lamp will be lit. Drive ready for speed command.

6.3.2 Thruster Stop Sequence

The Stop function is performed either from the K-Thrust Lever panel or from the K-Chief operator station if the thruster plant is selected to Maintenance Mode.

Upon a stop command the K-Thrust system will set the thruster rpm command to 0 RPM. It is important to set the thruster in the proper azimuth parking position before stop.

The stop command will stop the modulation in the frequency drive.

The drive stop sequence can be activated from the lever panel when the START lamp is steady lit. If a timeout occurs an alarm is given on the K-Thrust/K-Chief system and the sequence will halt.

The lamps will start flashing while the sequence is active.

The STOP button will do the following when activated:

Thruster stop sequence:

Step	Action	Condition for next step	Timeout	Remark
1	Deactivate drive	Drive not running	30s	The stop command will disable the converter modulation, open the main breaker and discharge the converter
2	Waiting step 30 sec	Position ok	60s	Allowing drive to stop, Force to Parking Position
3	Stop hydraulic pump	Hydraulic Steering pump not running	30s	The hydraulic pump continues to run for 60 sec after thruster stop is confirmed and until the steering feedback is 0deg.
4	Waiting step	Wait for 10 min after drive has stopped	10min	30 sec Thruster Still Cooling Down
5	Stop lubrication pump	Lub oil pump not running	30s	The lubrication pump continues to run for 60 sec after thruster stop is confirmed and until the steering feedback is 0deg.
6	Stop transformer fans Stop thruster motor fan			The thruster motor fan continues to run for 60 min after thruster stop. The thruster transformer cooling fans shall also run for 60 minutes after thrusters stop.
End				The STOP button lamp will be lit

6.3.3 Maintenance Mode

The Maintenance mode works in almost the same way as a normal thruster start sequence. In this mode K-Chief can initiate a Start Aux or Stop Aux sequence and run the Azimuth.

In this mode it is not possible to start or stop the thruster drive (rpm).

The Maintenance mode is selected by means of a soft button on the K-Chief mimic.

The selection of Maintenance mode is inhibited if the thruster is running.

The Maintenance mode will be deselected if Azimuth Local control is initiated.

When the Maintenance mode is selected the "External command" lamp on the lever panel of the corresponding thruster will be lit, as the command of the thruster is transferred from the RCS lever position to the K-Chief OS in command.

The Azimuth setpoint can be manipulated from the AzimCtr operator (popup) dialogue on the K-Chief OS thruster mimic after a successful Start Aux sequence.

6.3.3.1 Maintenance Thruster Start/Stop Aux Sequence

If a timeout occurs during the start sequence (see table below), an alarm is given on the K-Chief/K-Thrust system.

- The Start Aux sequence:

Step	Action	Condition for next step	Timeout	Remark
1	Hydraulic pump in Auto Lubrication pump in Auto Transformer fans in Auto Thruster motor fan in Auto Drive in Auto		30s	Setting auxiliaries in auto prior to start
2	Start transformer fans Start thruster motor fan Start CSW pump and FWC pump if not already running	Min. one Cooling fan running Motor Cooling fan running Min. one FWC pump running Min. one CSW pump running	30s	Starting cooling systems Start CSW pump and FWC pump if not already running
3	Start lubrication pump Start hydraulic pump	Lub. Oil Pump running Hyd. Pump running	30s	
End				Azimut ready for steering control

- The StopAux sequence:

(Note that this sequence is interlocked if the thrusters are running.)

Step	Action	Condition for next step	Timeout	Remark
1	Deactivate drive	Drive not running	30s	The stop command will disable the converter modulation, open the main breaker and discharge the converter
2	Waiting step 30 sec	Position ok	60s	Allowing drive to stop, Force to Parking Position
3	Stop hydraulic pump	Hydraulic Steering pump not running	30s	The hydraulic pump continues to run for 60 sec after thruster stop is confirmed and until the steering feedback is 0deg.
4	Waiting step	Wait for 10 min after drive has stopped	10min	30 sec Thruster Still Cooling Down
5	Stop lubrication pump	Lub oil pump not running	30s	The lubrication pump continues to run for 60 sec after thruster stop is confirmed and until the steering feedback is 0deg.
6	Stop transformer fans Stop thruster motor fan			The thruster motor fan continues to run for 60 min after thruster stop. The thruster transformer cooling fans shall also run for 60 minutes after thrusters stop.
End				The STOP button lamp will be lit

6.3.4 Sequence Start Interlock

The following parameters will cause start prevention:

Description	Yard Tag	LIM	SigTyp	Remark
THRUSTER #1 Power Available	SOW		DI	Software function, handled by the module ConsStart. PowerAvailable limit = 0
THRUSTER #1 DRIVE FAILURE	MIC-021102		DI	Open when failure
THRUSTER #1 Internal ShutDown Active		-	DI	

THRUSTER #1 DRIVE NOT IN REMOTE MODE	MC-021105	-	DI	DRIVE: LOC/REM : Opened when NOT in remote
THRUSTER #1 WERTSILA NOT IN REMOTE MODE	XI-021124	-	DI	LOC/REM : Opened when NOT in remote
Drive NFU Selected	XI-0211132		DI	
BlackOut				
Thruster NFU Selected	XI-021129		DI	
Ready To Start	MI-021101			
THRUSTER #1 MOTOR COOLER LEAK	XA-021207		DI	Open when failure
THRUSTER #1 WERTSILA MAJOR FAILURE	XA-021136	-	DI	Open when failure
LEVER THRUST < 10%	SOW		DI	Open when lever set point greater than 10 % thrust
Tc1Seqadm	SOW			Start Sequence TimeOut

Table 6.1 Thruster block start

When no sequence start interlock is present and the thruster systems are in remote operation, the “Ready to Start” lamp on the lever panel to be lit.

Note that hardwired signals between the Drive and the Azimuth act as the thruster start block signal.

6.3.5 Drive Start Block

6.3.5.1 Drive - Azimuth Controlled Safety Start Block

The Drive will not be activated if one of the following conditions is present:

	Description	**Yard Tag**	**LIM**	**SigTyp**	**Remark**
1 2	THRUSTER #1 LUB OIL PRESS NOT OK	PAL-021305 PAL-021306	1.7bar	AI	Opens on alarm, block start when open

	Description	Yard Tag	LIM	SigTyp	Remark
3	THRUSTER #1 LUB OIL SUPPLY PUMP NOT RUNNING OK	MI-121301A or MI-121301B	-	DI	Opens when not running. Block start when open.
4 5	THRUSTER #1 STEER OIL PRESS 1 or 2 NOT OK	XI-021130 or XI-021148	-	DI	Opens on alarm, block start when open
6	THRUSTER #1 STEER OIL PUMP 1 or 2 NOT RUNNING OK	MIC-021401 or MIC-021402	-	DI	Opens when not running. Block start when open.
7	THRUSTER #1 CFW PP NOT RUNNNING OK (Pump not running (open when not running)	MIC-021604 MIC-021605 MIC-021606	-	SOW	One set of duty / standby CFW pumps work for each thruster.
8 9 10	Running and discharge pressure not ok Pump running but the discharge pressure is in alarm condition (Open when in alarm condition)	PAL-021603A PAL-021603B PAL-021603C			
11	THRUSTER #1 MOTOR COOLING FAN NOT RUN	MIC-021211	-	DI	Opens when not running
12	THRUSTER #1 TRANSFORMER COOLING FANS NOT RUN	DS-021212		SOW	This SW contact shall be healthy when one fan is running otherwise it shall be open.MIC-021212 AND MIC-021213
13	DCU Start Block	MC-021109			
14	CSW Pumps Not Running	MIC-021702 MIC-021703			

Table 6.2 Thruster block start

Note that this safety start block functions independent of the K-Chief/K-Thrust system. Some conditions may be possible to monitor on the K-Chief OS (ref IO List).

This table might be incomplete. Please ref VFD and Azimuth vendors FDS

6.3.5.2 K-Thrust Controlled Start Block

The Drive Start Block will inhibit the K-Thrust system executing the start command to the thruster drive, and is in addition to Drive Startblock.

KM will also check the following items:

Description	Yard Tag	LIM	SigTyp	Remark
POWER NOT AVAILABLE	POW-121135		SOW	Sufficient spare capacity available on the respective switchboard for start-up.
Drive Shutdown	TC1FailStop		SOW	Thruster shout down by executed failur
Maintenance mode active			SOW	
THRUSTER #1 LUB OIL PRESS NOT OK	PAL-021305 PAL-021306	1.7bar	AI	Opens on alarm, block start when open
THRUSTER #1 LUB OIL SUPPLY PUMP NOT RUNNING OK	MI-121301A or MI-121301B	-	DI	Opens when not running. Block start when open.
THRUSTER #1 STEER OIL PRESS 1 or 2 NOT OK	XI-021130 or XI-021148	-	DI	Opens on alarm, block start when open
THRUSTER #1 STEER OIL PUMP 1 or 2 NOT RUNNING OK	MIC-021401 or MIC-021402	-	DI	Opens when not running. Block start when open.
THRUSTER #1 CFW PP NOT RUNNNING OK (Pump not running (open when not running)	MIC-021604 MIC-021605 MIC-021606	-	SOW	One set of duty / standby CFW pumps work for each thruster.
Running and discharge pressure not ok Pump running but the discharge pressure is in alarm condition (Open when in alarm condition)	PAL-021603A PAL-021603B PAL-021603C			
THRUSTER #1 MOTOR COOLING FAN NOT RUN	MIC-021211	-	DI	Opens when not running

Description	Yard Tag	LIM	SigTyp	Remark
THRUSTER #1 TRANSFORMER COOLING FANS NOT RUN	DS-021212		SOW	This SW contact shall be healthy when one fan is running otherwise it shall be open.MIC-021212 AND MIC-021213
DCU Start Block	MC-021109			
CSW Pumps Not Running	MIC-021702 MIC-021703			

Table 6.3 Thruster block start

6.4 Shutdown/Safety Stop

6.4.1 Drive Controlled Shutdown

The thruster will be shut down by the Drive in the following events:

Thruster shutdown is executed when:

Description	Tag	LIM	SigTyp	Remark
THRUSTER #1 WERTSILA OIL HIGH TMP	TAHH-021411		DI	LimitHH =80Deg C
THRUSTER #1 EXPANSION TK LOW LOW LVL	LALL-021501B	-	DI	
THRUSTER# 1MOTOR DRIVE BEARING TEMP HIGH HIGH			SOW	FROM TIAH-021205 AND TIAH-021206
THRUSTER# 1MOTOR DRIVE WINDING TEMP HIGH HIGH			SOW	From TIAH-021201 ⇒ TIAH-021203 LimitHH & Sensor OK
THRUSTER# 1MOTOR TRANSFORMER WINDING TEMP HIGH HIGH			SOW	From TIAH-032501 ⇒ TIAH-032503 LimitHH & Sensor OK
THRUSTER #1 EMCY STOP FROM K-THRUST		-	-	Hard wired signal from K-THRUST to converter

Table 6.5 Thruster fail stop

These safety shutdown functions are independent of the K-Chief/K-Thrust system.
Some conditions may be possible to monitor on the K-Chief OS (ref. IO List).

This table might be incomplete. Please ref VFD and Azimuth vendors FDS

When a shutdown is initiated the K-Thrust lever panel “Shutdown” lamp will flash and a buzzer sound.

When ready for DP signal (XI-021127) is lost, the failed thruster is deselected from DP.

6.4.2 K-Thrust Controlled Shutdown

In the event that any signals in the table below are activated, the stop sequence will be initiated and automatically stop the thruster/propulsion motor.

Description	Tag	LIM	SigTyp	Remark
THRUSTER #1 WERTSILA OIL HIGH TMP	TAHH-021411		DI	LimitHH =80Deg C
THRUSTER #1 EXPANSION TK LOW LOW LVL	LALL-021501B	-	DI	
THRUSTER# 1MOTOR DRIVE BEARING TEMP HIGH HIGH			SOW	FROM TIAH-021205 AND TIAH-021206
THRUSTER# 1MOTOR DRIVE WINDING TEMP HIGH HIGH			SOW	From TIAH-021201 ⇒ TIAH-021203 LimitHH & Sensor OK
THRUSTER# 1MOTOR TRANSFORMER WINDING TEMP HIGH HIGH			SOW	From TIAH-032501 ⇒ TIAH-032503 LimitHH & Sensor OK
THRUSTER #1 EMCY STOP FROM K-THRUST		-	-	Hard wired signal from K-THRUST to converter

Table 6.6 Thruster fail stop

In the event of a shutdown, any start or stop sequence is aborted.

6.5 LO and Steering oil Pump Control

The LO and steering oil pumps are normally controlled by the K-Chief system.

These pumps are started and stopped automatically by K-Chief start/stop sequences when selected in auto by the operator.

They can, however, be selected to manual and started and stopped remotely by the operator from the K-Chief VDU mimic.

The third possibility is a control on the local MMC starter.

6.6 Thruster Cooling

The cooling system FW an SW pumps are controlled by the start sequences.

If the pumps are not already running they will be started by the start sequence. The pumps will not be stopped by the stop sequence. That is a manual operation.

Se more information in the Machinery FDS.

6.7 Thruster Motor Fan Control

Automatically start of the Thruster Motor Fan upon thruster start and automatically stop of the fan 60 min after thruster stop has been confirmed is prepared.

If the fan is stopped while the thruster is running an alarm is generated.

6.8 Thruster Transformer Fans Control

Each transformer is provided with 2 (two) Transformer cooling fans. These fans operate on lead lag mode. The IAS will start the lead fan whenever the thrusters main CB is closed or during a start sequence of thruster. In the event of high alarm of any transformer winding temperatures (TIAH-032501, 502 and 503) the lag fan starts and continues to run till 5 minutes after all the transformer winding temperatures have come to normal state. In the case of high high alarm of any transformer winding temperature IAS will shutdown the thrusters drive. The lag fan also starts whenever the running lead fan stops. In this case the lag fan shall not stop even if all the transformer-winding temperatures are in normal state. The running fan automatically stops 60 min after thruster stop has been confirmed. If both the fans are not running for a time longer than 30 seconds while the thrusters is running an alarm is generated.

6.9 The Lever Reset Button

The Lever reset button has two primary functions, to reset the Drive and reset/abort any start/stop sequence.

The Drive can be reset from the RESET button on the K-Thrust lever panels or from the VDU mimic when in maintenance mode. Note that some failures may not be reset remotely and that these failures require reset on the Drive locally. Before a reset any alarms need to be checked out by qualified personnel. See Drive vendor documentation for more details.

6.10 Thruster Blackout Restart

Ref. FDS Power Management System

Note that the K-Thrust blackout restart sequence will initiate a reset of the Drive before continuing the BOstart sequence. The BO restart will try to reset the Drive 3 times before aborting.

Note: The BO Startsequence will inhibit all interlocks.

If the BO duration is lasts longer than 10 minutes there will be no auto restart of the thruster, and the thruster needs to be started as normally from the lever panel.

During a blackout restart the IAS will send a blackout start up signal to thruster drive (ABB) and thruster (Wartsila). (XC-021147, XC-022147, XC-023147, XC-024147, XC-025147, XC-026147 and XC-021152, XC022152, XC023152, XC024152 XC025152, XC026152). These signals informs the thruster drive and thruster that we are in a blackout recovery process.

6.11 Thruster Load Limitation

See K-Chief FDS Power Management System Chapter: Consumer Load Limitation.

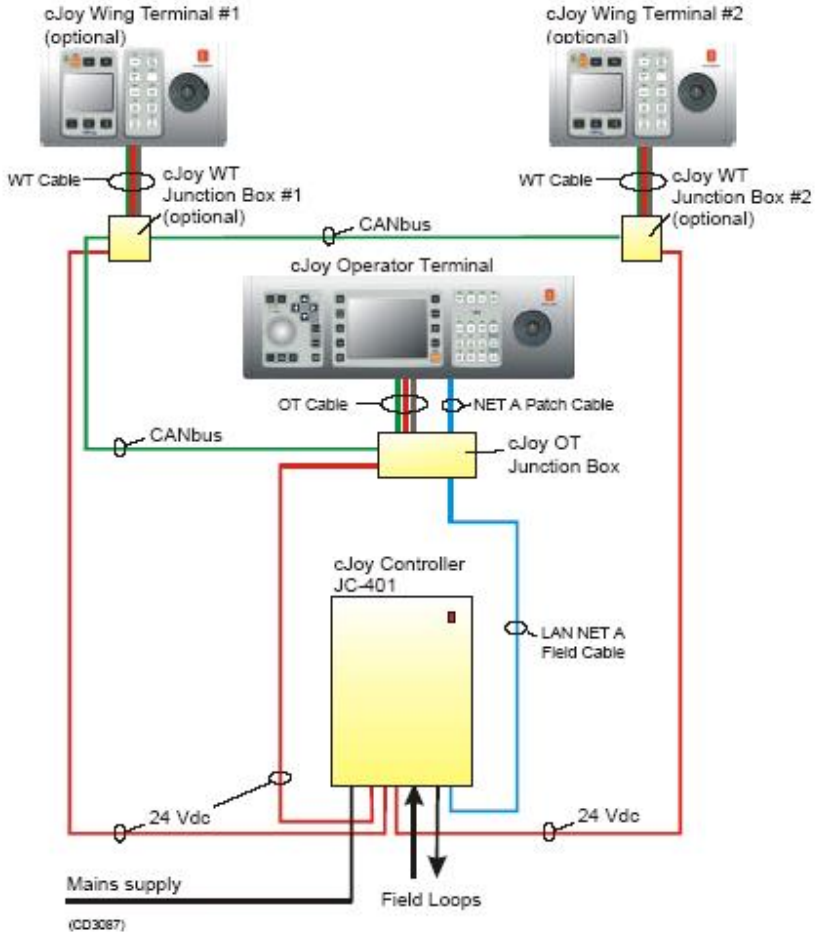
6.11.1 Power Limit Lamp

The K-Thrust lever panel “Power Limit” status lamp will lighten when the drive gives the Power Reduction Active feedback. Under normal conditions this feedback is given when the drive reduces load due to the load limitation/power available signal calculated by the K-Chief PMS system. However, this feedback can also be given when enough power is available and when the drive does an automatic limitation due internal / overload conditions.

The operator should ease off on the throttle if this lamp is lit.

6.12 Thruster C-Joy Control

A separate independent joystick system is connected directly to the thruster control system. Everything is separated from the DP control system. The azimuth/RPM command and feedback will go direct to the thruster cabinet. The C-Joy mode are selected on the Utility panel at the K-Thrust consol, this signal will then go directly to each thruster cabinet.



6.13 Engine Telegraph

Engine telegraph system is fitted in this vessel. The Master panels (2ea) are located in the Bridge. The slave panels will be located nearby the Thruster 4 and Thruster 5. Operator after receiving the telegraph can adjust the speed of the Thruster by adjusting the setting on the manual panel located on the front facia of the Thruster process station. The azimuth angle can be adjusted locally from the Wertsila unit front facia as per the instructions of the bridge operator. In the worst scenario the sound powered telephone can be used for receiving the instructions from bridge.

6.13.1 Shaft Brake Control

The shaft brake control is mechanical and local only. There is no IAS control over the shaft brake. The shaft brake opened condition is a pre requisite for thrusters control from IAS and is merged into “Thruster Ready for DP operation” signal.

The local mechanical shaft brake will automatically engage with shaft speed below 60 RPM. This is fully controlled by Wartsila thruster and will not affect the Ready for DP signal during DP operation.