

1 GENERAL DESCRIPTION

1.1 INTRODUCTION

This manual was produced for the 300t Deep Water Lifting System

The 300t DWLS is designed according to:

- Lloyds Code for Lifting Appliances in a Marine Environment, January 2003
- Man riding is designed according to the NEN-EN 13852-1, June 2004

WARNING



Operation of this system is prohibited to any person without full knowledge and understanding of this manual.

WARNING



It is strictly prohibited to carry out any heat treatment on the 300t DWLS, such as welding, cutting or grinding. The DWLS is made of high tensile steel and therefore requires special heat treatment procedures.

1.2 SYSTEM OVERVIEW

Reference drawings:

The 300t Deep Water Lifting System comprises the following main components:

- Deck beam with swivel
- Heave compensation system
- 300t Traction winch
- 15t Storage winch with spooling device

1.2.1 Main characteristics

The system includes a movable deckbeam which supports the hoist sheaves and is placed towards the moonpool or on either side of the vessel. The hoist is single fall. The wire is guided over a number of sheaves to the traction winch which is placed below deck. The wire is stored on a storage winch placed behind the traction winch. The linepull of the storage winch is kept at a constant tension of 15t. In two sheaves (one in high tension, one in low tension rig) a loadpin is mounted which measures the load in the hook.

Between the traction winch and the deckbeam a heave motion compensator is mounted. The compensator will be used to compensate for the vertical vessel motion, but only at the moment the load is placed on the seafloor. The paid out length of the wire is shown at the operator display.

- See Figure 1-1 for an overview of the 300t DWLS and the positions of its main components;
- Refer to Appendix A: "Technical specification" for more details on the various components.

WARNING



The system may only be used for the purpose it was designed for, and only within the limits of the design criteria.

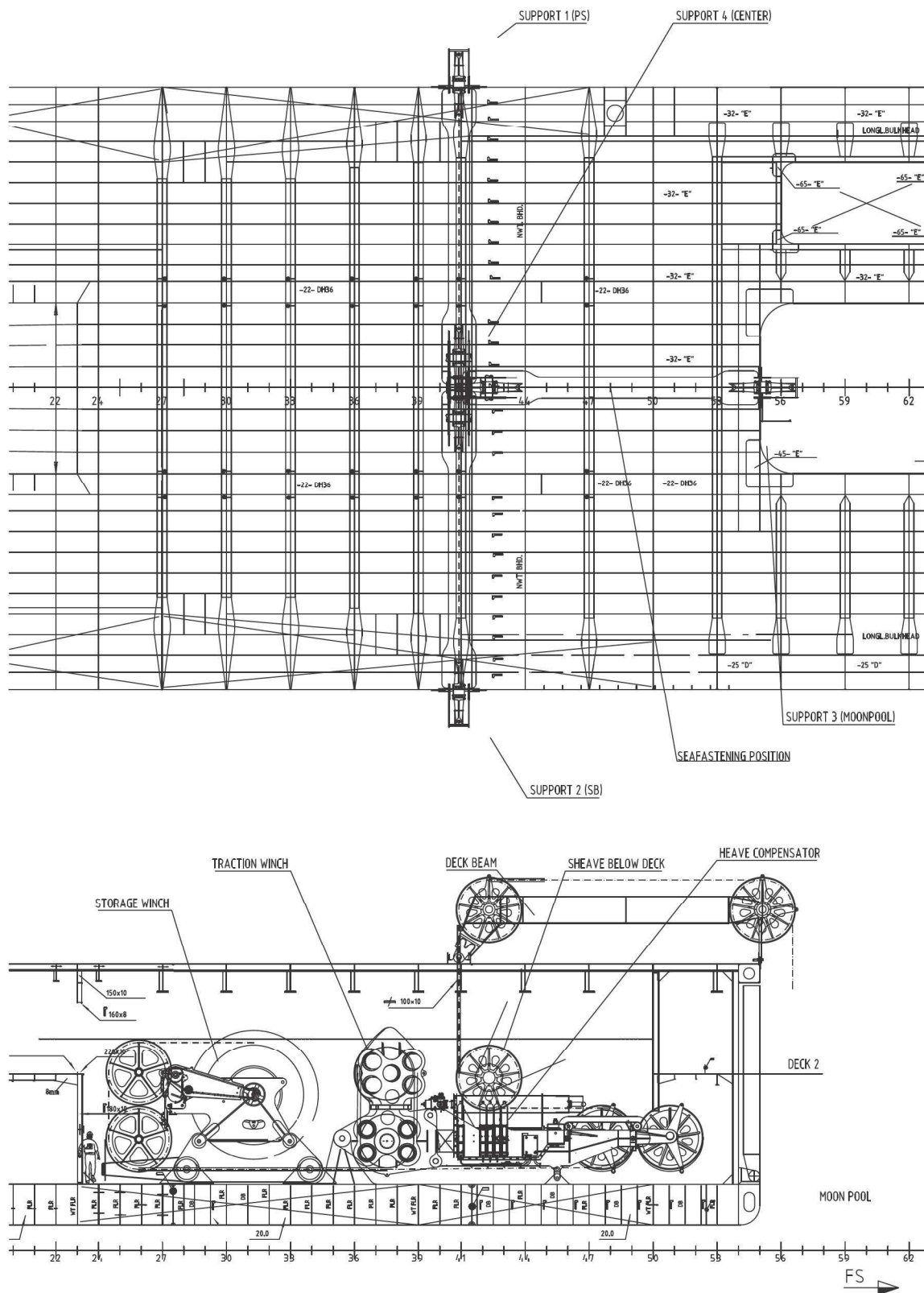


Figure 1-1: Overview 300t DWLS

1.3 SAFETY

This section provides some general safety prescriptions. Detailed safety information is given wherever appropriate in the next sections.

1.3.1 General safety prescriptions

- Prior to operating, maintaining or repairing the system, all instructions and safety regulations in this manual as well as in the suppliers documentation must have been read and fully understood by all personnel who will be working with, or in the vicinity of, the DWLS.
- The load specifications as well as the environmental conditions as described in this manual may NOT be exceeded. It is strongly advised to STOP the DWLS before it reaches its limits! In case of any doubt on the definition of the operating conditions,
- No persons are allowed near or on the system during operation, without prior knowledge and consent of the operator.
- The system may only be operated by an authorised operator, who is well trained and experienced in operating similar equipment, and who has full knowledge and understanding of the contents of this manual.
- Regular maintenance, service and inspection are required in order to guarantee safe use of the system for the duration of its lifetime. Maintenance may only be carried out by well-trained and experienced personnel.
- Before starting maintenance or repair activities, make sure that all electrical power is disconnected and that all components are in a safe position. Always secure moveable parts that could present a risk of injury or damage.
- Welding operations to the main structure or any other heat treatment can influence the system's integrity or fatigue life. It is therefore not allowed to carry out any welding, grinding or
- The keys of key switches used for operation must be kept in a safe place by an authorised person (supervisor) when not in use. The key switches may only be used when the person concerned has full knowledge and understanding of any possible consequences of doing so.
- The operator must have clear view of the system and its direct vicinity during operation.
- External noise level from activities in the surrounding area can be considerable. In this case it is the captain's responsibility to supply hearing protection (ear muffs, ear plugs etc.)
- During sea travel, or when the maximum operating conditions are exceeded, the system must be seafastened.

1.3.2 General safety signs

The following safety signs are to be applied at the appropriate locations in the system.

SYMBOL	MEANING
	Keep away from moving loads. Extreme caution is required.
	General warning sign. Caution is required (e.g. moving machine parts).
	Potentially lethal voltages are present in the cabinets.
	Wear safety gloves to protect skin from aggressive cleaning or maintenance products.
	Wear safety glasses.
	Wear safety boots.
	Wear ear protection.
	Wear a safety helmet.

It is responsibility of the client to apply the appropriate safety signs / labels at the appropriate locations in the system (e.g. warnings for moving loads, dangerous voltage etc.)

1.3.3 Safety provisions

The DWLS is provided with the following safety provisions (detailed information can be found in the corresponding sections):

- <Safety provision 1>
- <Safety provision 2>
- <etc.>

Remarks

Fail-Safe

The electrical system is designed as fail-safe. A malfunction or error of a specific sensor, device, circuit (wire break) or system will result in a transition to a safe situation.

Safety switches

Safety switches (i.e. emergency stops) are regarded as normally closed contacts. Failing of the switch or discontinuity of the cable will therefore result in a stop.

2 MECHANICAL DESCRIPTION

2.1 INTRODUCTION

Reference drawings:

- A06-74000-00-10F: 300t DWLS interface
- A06-74000-31-108: DWLS Reeving diagram
- A06-74000-10-108: Deck beam
- A06-74010-10-008: Heave compensator
- A06-74020-00-018: Traction winch & Heave compensator
- A06-74030-00-018: Storage winch
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- A06-74100-31-018: PMOC Reeving diagram

The drawings referred to are provided in Appendix D: "Reference drawings - Mechanical".

This section describes the mechanical and constructional aspects of the 300t Deep Water Lifting System. The DWLS comprises the following subsystems:

- a deck beam with swivel, provided with steel wire rope (diameter 109mm, length 3000m);
- a heave compensation system to facilitate subsea lifts;
- a 300t two-drum traction winch to provide the required line pull;
- a 15t storage winch for storage of the required wire rope length, equipped with a spooling device to ensure proper spooling;

The storage winch operates with a constant tension (CT) and thus provides back tension to the traction winch so that there can be enough friction build-up between the wire rope and the two drums of the traction winch to generate the high line pull. The CT mode of the storage winch also prevents the rope from slackening. The storage winch is equipped with a spooling device to lead the 109mm wire rope to the traction winch in a controlled manner and to reduce the fleet angle.

Load measurement and overload protection is done by means of a load cell in the top sheave of the heave compensator and another one in the lower of the storage winch fairlead sheaves. See Appendix U: "Load cell documentation" for more information on the load cells.

Length measurement of the paid-out wire rope is done by means of a toothed sheave connected to the spooling device fairleader and two proximity switches. A geared limit switch connected to the storage winch drum shaft safeguards the end positions (empty and full drum).

NOTE	<i>Hoisting the load will reduce the force on the wire rope because the weight of the wire rope decreases, while lowering will increase the load. An overload could occur if the operator tries to lift more than the specified weight. In order to prevent this, the weight of the load to be lifted has to be known. It should then be checked if the required depth can be reached with the current load on the wire rope (the weight of the rope is decisive).</i>
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2.2 STRUCTURAL COMPONENTS

2.2.1 Deck beam & swivel

Reference drawings:

- A06-74000-10-108: Deck beam
- A06-74000-32-108: Sheave
- A06-74000-33-208: Swivel 300t SWL

The deck beam holds a hoisting wire for lowering constructions with a maximum weight of 160 mt ton to maximum depth of 3000m. On the deck beam two sheaves are positioned, which can guide the wire into three positions on the deck:

- moonpool
- portside
- starboard

The load will not be guided; at the end of the wire a swivel is used to prevent rotation of the wire.

2.3 MECHANICAL DRIVE COMPONENTS

2.3.1 Heave Compensation System

Reference drawings:

- A06-74010-10-008: Heave compensator
- A06-74010-10-408: Sheave block
- A06-74010-46-108: Load pin

The Heave Compensation System (HCS) will be used when lowering or hoisting loads from or to the seabed. When a load is lowered to the seabed the position of the ship in relation to the seabed will change because of heave and roll motions. As a result of this movement the load will also move up and down. The heave compensation system will start to move in and out under influence of the initiated drag and acceleration forces from the load.

The main cylinder used for heave compensation can also be used as a shock absorber to protect the crane structure against overloading.

The heave compensation system consists of a passive part and an active part. The passive system consists of a gas loaded spring system connected to the hoist wire. The spring system extends or retracts depending on the tension in the hoist wire. It comprises a main cylinder connected through a medium separator to a battery of pressure vessels charged with nitrogen pressure. By varying the pressure of the gas and the number of connected PVU's, the spring system can be adjusted to different static loads. Due to the stiffness of the gas system the tension in the hoist wire changes if the passive cylinder moves in and out.

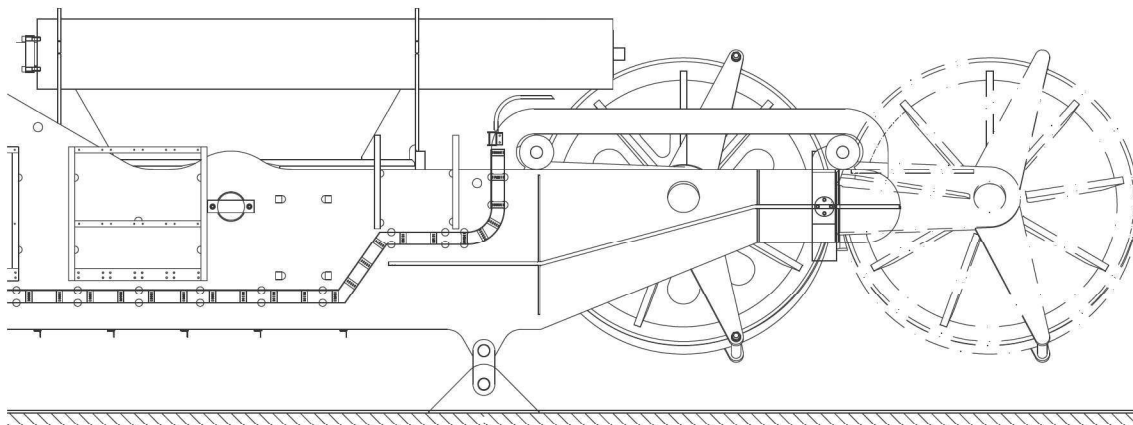


Figure 2-6: Heave compensator

Vessel motions caused by waves or accelerations at the winch can increase or decrease the linepull for short periods of time. For example; when a vessel that is hoisting a submerged load receives an upward acceleration, the linepull increases. When the linepull tends to exceed its nominal value, the cylinder will retract until the gas pressure is in balance with the load. While the cylinder is retracting, wire is paid out without affecting the winch movement. By paying out wire, an increase in linepull is limited.

When the linepull tends to decrease below its nominal value, the cylinder will extend until the linepull returns to its nominal value. While the cylinder is extending, wire is hauled in without affecting the winch movement. By hauling in wire, a decrease in linepull is limited.

As the load forces always have a phase lag in relation to the position of the load itself and as these forces are dependent on the weight and size of the load, the passive system cannot fully compensate ship motions.

The active heave compensator therefore adds two so-called active cylinders to the system. These cylinders are mechanically connected to the main cylinder and are controlled by the active valve that receives its control signal from the automatic control system. The active cylinders assist the main cylinder to extend or retract. The major part of the external load (the static component) is supported by the passive main cylinder. The active cylinders only have to overcome the load that is caused by the varying nitrogen pressure plus the resulting unbalance between average nitrogen pressure and average load. The pressure in the pressure vessels has to be in balance with the average external load of the system. The better this is achieved the less the active cylinders have to compensate. Refer to Section 3: "Hydraulic description" and Section 5: "Operation" for a more extensive description of the heave compensation system.

2.3.2 Traction winch

Reference drawings:

- A06-74020-00-018: Traction winch and heave compensator
- A06-74020-00-10C: Interface

The traction winch (Figure 2-7) is located below deck and basically consists of two winches located above each other in a common winch frame. The traction winch principle is based on friction build-up between the two capstan drums and the wire rope.

The drum axes are mounted in an angle relative to each other, which results in a fleet angle of zero degrees. This reduces wire rope fatigue because there is no build-up of torsion in the rope while running over the capstan drums. The drums are provided with exchangeable hardened and grooved sleeves to prevent wear of the drum surface. The groove diameter of the traction winch decreases with every wrap in order to cope with the elastic elongation of the wire rope when tensioned. This type of grooves eliminates slipstick effects of the wire rope on the drum.

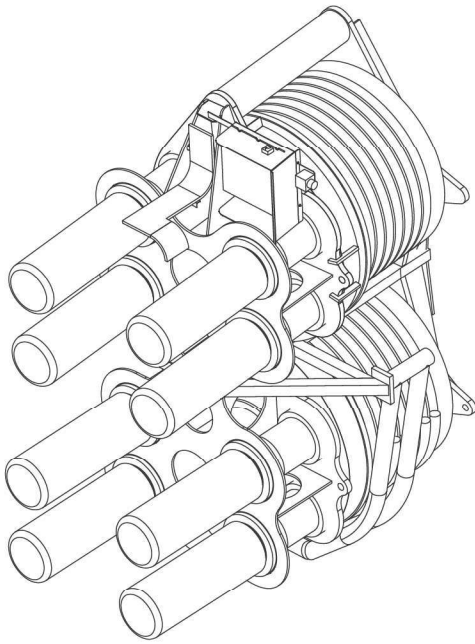


Figure 2-7: Traction winch



Figure 2-8: Zero fleetangle between drums

The traction winch delivers a linepull of 320t. No wire is stored on the drums of the traction winch; this is done on the storage winch, which also provides a backtension of 15t to the traction winch.

The winch drums are each driven by means of four E-motor-gearbox combinations. The pinions on the gearbox shafts engage in a gear ring bolted to the winch drum. On the other side the drum is suspended on a shaft with a bearing. Like the storage winch drives, each of the traction winch drives is provided with its own disc brake that is lifted electromagnetically and applied mechanically by spring pressure.

The gear rings of the traction winch are lubricated by means of an automatic lubrication system (make Vogel, refer to Volume III - Supplier documentation for details). A sensor is provided for detection of an empty lubricant reservoir.

2.3.3 Storage winch

Reference drawings:

- A06-74030-00-018: Storage winch - General arrangement
- A06-74030-00-10B: Interface
- A06-74030-21-108: Winch frame
- A06-74030-21-208: Winch drum
- A06-74030-21-308: Slewing bearing, chain & mainshaft

The storage winch (Figure 2-9) is part of the DWLS system and is located below deck. It basically consists of a large drum for storage of the A&R wire rope and a mechanically coupled spooling device (see section 2.3.3.1) to guide the rope to or from the traction winch. A gearcam limit switch on a shaft at the winch drum monitors the minimum and maximum number of layers on the drum.

The drum is driven by means of a large slew bearing bolted to the winch drum. Two pinions, each on the outgoing shaft of a gearbox and driven by means of an electric motor, engage in the gear ring of the slew bearing and thus rotate the drum. At the other end the drum is suspended on a shaft with a bearing.

The spooling device consists of a swing arm with 2 sheaves driven by a diamond screw shaft. It ensures the fleet angle does not exceed 1.5 [deg].

Both drives are provided with an electromagnetic disc brake. These brakes are spring-applied fail-safe parking brakes, which means that they are applied automatically by means of a mechanical spring in case of failures, at standstill or when no power is available. During operation the brakes are lifted by electrical power.

The winch operates in constant tension mode at a constant line pull of 15mt in all layers. The load in the wire is indicated by a loadcell. The winch is however a very rugged winch capable of handling a very large overload which may be caused during power failure or emergency stop. In these situations the brakes are applied when the traction winch is still pulling. This causes the brakes of the storage winch to slip for about one second until the traction winch has come to a complete stop.

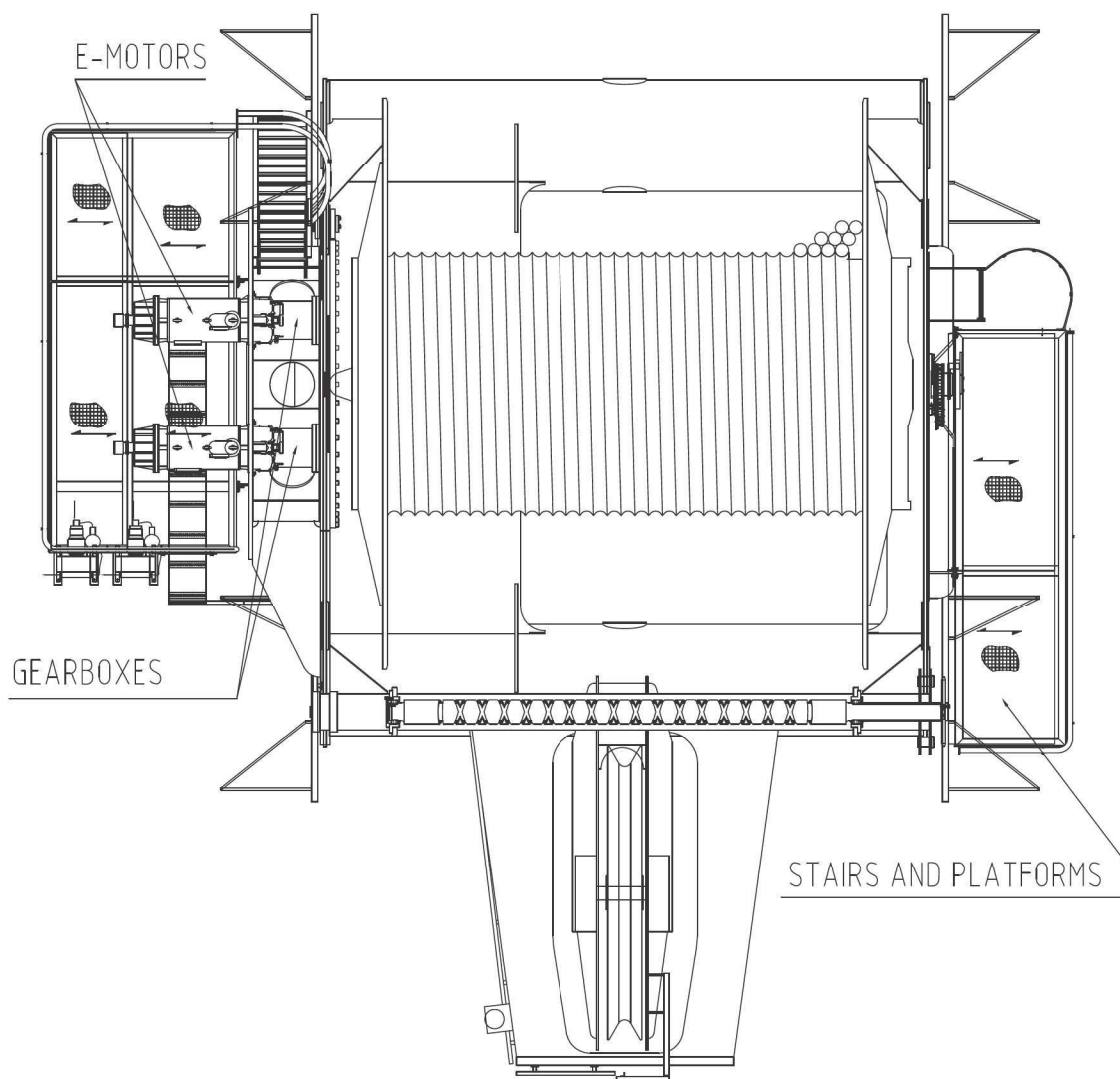


Figure 2-9: Storage winch with spooling device

The rope end is secured to the drum using 6 x M30 8.8 bolts and a clamping plate. These bolts need to be tightened with a torque of 300Nm. A minimum of 5 safety windings must always remain on the drum.

A lot of components on the storage winch and spooling device need regular lubrication. Refer to Appendix I: "Greasing schedule(s)" for details on grease types and greasing intervals. For details and maintenance instructions on the slew bearing and gearboxes (Liebherr), the E-motor (Wölfer) and the disc brakes (Pintsch Bamag) refer to Volume III - Suppliers documentation.

2.3.3.1 Spooling device

Reference drawings:

- A06-74030-21-408: Spooling device arm
- A06-74030-21-508: Spooling device frame, trolley, shaft
- A06-74030-21-608: Chain tensioner spooling device drive
- A06-74030-22-108: Slewbearing
- A06-74030-24-108: Gearbox
- A06-74030-46-108: Load pin

To guarantee a proper spooling behaviour of the wire rope and to lead it to the traction winch in a controlled manner (max. fleetangle 1.5°), a spooling device is mounted in front of the winch. The spooling device consists of a diamond screw shaft connected to the storage winch drum by means of a chain transmission, see Figure 2-10. The diamond screw shaft drives a block with two wire rope guiding rollers that moves from left to right and follows the spooling direction of the wire rope. A pin on the block fits into the groove of the diamond screw shaft and will turn automatically at the end of the stroke. The chain is kept at the right tension by means of an adjustable chain tensioner. A proximity switch detecting the chain ensures that the winch is stopped in case of a broken transmission chain, see Figure 2-12.

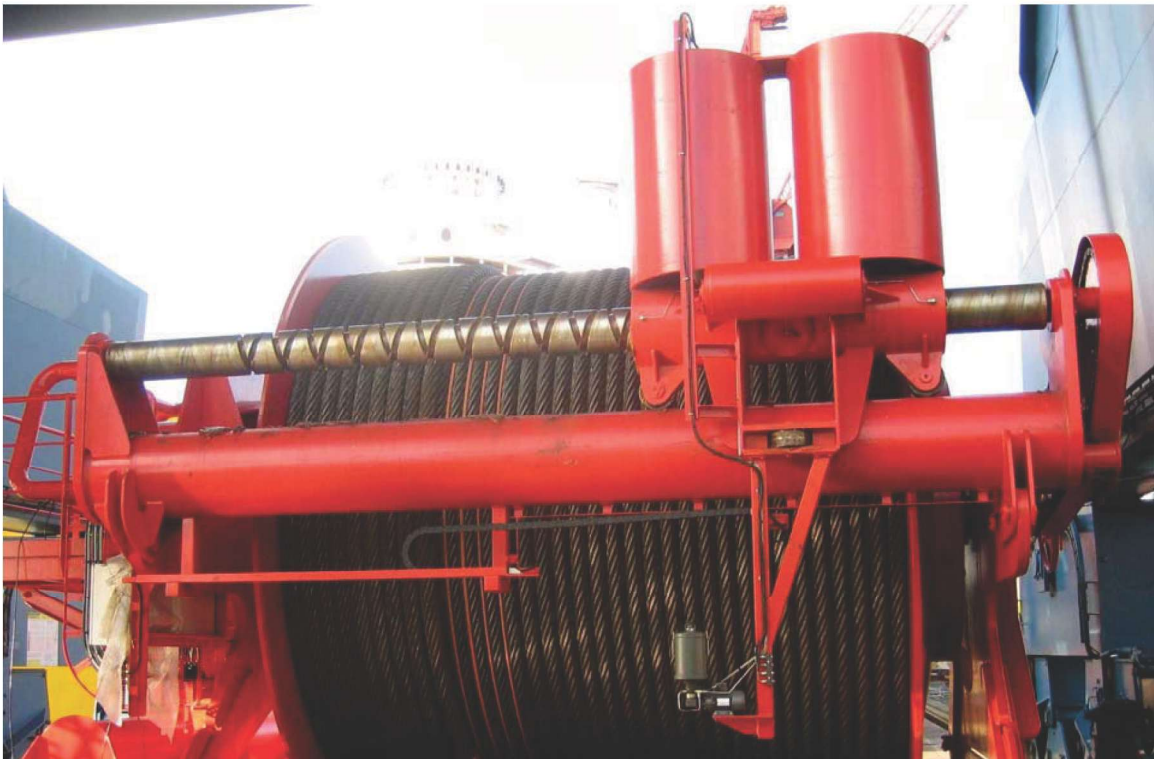


Figure 2-10: Spooling device

WARNING

Always keep a close watch on the spooling mechanism during operation. If the pin on the wire rope guiding block should fail to turn at the end of the stroke or if something should get stuck in the groove and prevent the pin from continuing its path, this would result in the wire rope not being spooled properly on the winch. Operation should then be stopped immediately until the fault has been resolved.

The spooling device is greased by an automatic grease system. The grease type and filling quantity of the reservoir are indicated on the greasing schedule. The lubricant level in the reservoir is monitored and an alarm is given when an empty reservoir is detected. Refer to Volume III - Supplier documentation for information on the grease pump.

The position of the wire rope guiding rollers relative to the drum can be adjusted by turning the hand wheel attached to the chain sprocket at the drum shaft. Normally, this only needs to be done in well defined cases, see warnings below. To adjust the spooling device unscrew the securing bolt and take out the lock pin, see Figure 2-11. By turning the wheel the position of the wire rope guiding block on the diamond screw shaft can now be changed.



Figure 2-12: Chain tensioner and proximity switch

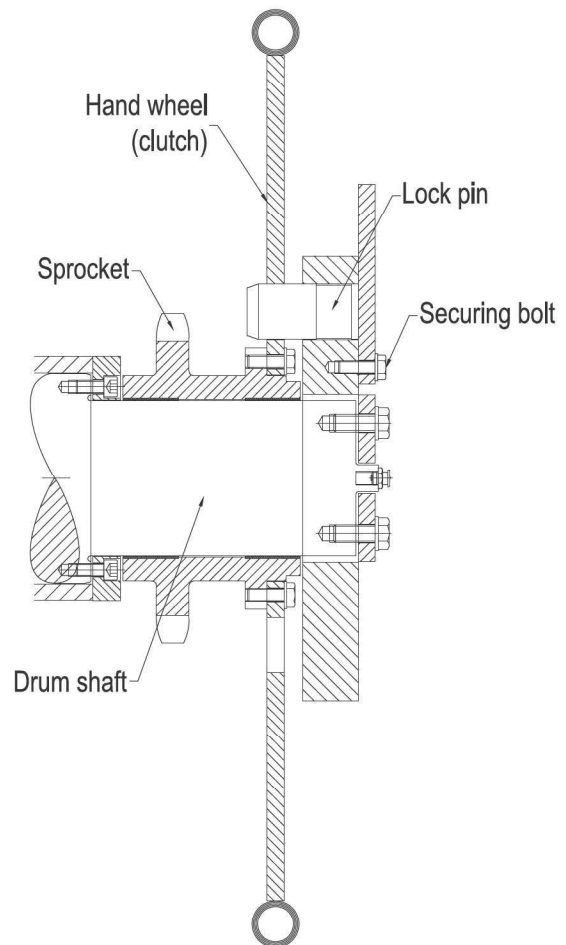


Figure 2-11: Adjustment principle

WARNING

Synchronize the spooling device and the storage winch drum after replacement or modification of the wire rope!

3 HYDRAULIC DESCRIPTION

3.1 INTRODUCTION

Reference drawing:

■ A06-74010-80-008: Hydraulic diagram - One-line diagram

This section discusses the hydraulic system of the 300t Deep Water Lifting System. The hydraulic system basically consists of the hydraulic power unit (HPU) and the heave compensation system (HCS). The drawings referred to are in Appendix L: "Reference drawings - Hydraulic"; the belonging parts lists are in Appendix Z: "Spare parts list(s)".

The codes of hydraulic parts and hoses are linked to the electrical function codes, see Appendix R: "Directives for code use" for an explanation.

3.2 HYDRAULIC POWER UNIT (HPU)

Reference drawings:

- A06-74010-80-108: Hydraulic diagram - Hydraulic power unit
- A06-74010-88-008: Hydraulic power unit

3.2.1 Introduction

The HPU (Hydraulic Power Unit or power pack) is located in the ships hold and is dedicated for the heave compensator only. The main parts of the HPU are:

- Reservoir with appendages
- Cooling and filtration circuit
- High pressure circuit

3.2.2 Hydraulic reservoir

Reference drawing:

- A06-74010-88-208: Hydraulic reservoir

The hydraulic reservoir (Z301) can contain 6500 litres of hydraulic oil. The reservoir is practically divided in two compartments. The drain lines and the return line enter in the first, so-called “dirt”, compartment. The return lines of the cooling and filtration circuit enter in the second, so-called “clean”, compartment. The main pumps (P102, P103) are supplied with oil out of the “clean”, compartment. The suction lines of the cooling/filtering pumps (P201) are connected to the “dirt” compartment while the pressure side is connected to the “clean” compartment. The suction of the off-line filtration pump (F401) is connected to the “dirt” compartment while the pressure side is connected to the “clean” compartment.

Filling of the reservoir is via ball valve (V211) mounted in the cooling and filtration circuit between the cooler (Z209) and the filter on the tank top filter (213). Sampling of the oil can be done from the measuring connection between the cooling and filtration pumps and the flushing filter (Z206).

Parts on the reservoir

The oil level can be read from the level gauge (Z005). Four switches mounted the level gauge are used for the Too high level, High level, Low level and Too low level alarms.

Level alarm		
Sensor	E-Code	Action
Too high level alarm	730B71	Stop all pumps
High level alarm	730B72	Alarm
Low level alarm	730B73	Alarm
Too low level alarm	730B74	Stop all pumps

To prevent overpressure in the reservoir, check valve (V007) is mounted. The cracking pressure of the check valve is 0.1 bar. To protect the reservoir from dirt out of the environmental air, tank breathers Z006 will filter the air. The breathers use a 3µm element. Draining the reservoir can be done with ball valves (V013A).

Temperature indicator/switch (S003) monitors the temperature of the hydraulic tank.

Temperature			
Sensor	Value	E-Code	Action
Too high temperature alarm	70 °C	730B51-1 (NC)	Stop all main pumps
High temperature alarm	65 °C	730B51-2 (NC)	Alarm
Low temperature alarm	35 °C	730B51-3 (NO)	Alarm
Too low temperature alarm	20 °C	730B51-4 (NO)	Not allowed to start main pump
Hysteresis	3 °C		

Off-line filtration unit

The suction side of the off-line filter unit (F401) is connected to the first, so called “dirt”, compartment. This filter unit contains a large 2µm filter element and is used as an additional filter to the system in order to achieve a higher cleanliness level. The filter is equipped with an optical dirt indicator. It is advised to keep the filter unit in operation at all times even when the system is not in use. This means that it is automatic started when one of the other pumps is started and must be stopped with its own stop button. Clean oil exiting the filter unit enters the second, so-called “clean”, compartment. Always make sure to open ball valves (V014) and when the off line unit is started for normal operation.

Return line

Filters (Z211) with a 20 µm element, filter the oil from the return line and entering the “dirt” part of the reservoir. The filter is not used to filter the oil to the specified cleanliness, but provided for safety reasons. Filter (Z211) is equipped with an electrical and optical clogging indicator that indicate a 5 bar pressure drop over the filter. The bypass valve opens when the pressure drop across the filter exceeds 6 bar.

Return line alarms		
Sensor	E-codes	Actio
Return filter ‘dirty’	730B40	Alarm
Return filter ‘dirty’	730B41	Alarm

3.2.3 Main system

3.2.3.1 Pumps

There are two main pump sets for the HP system. Each pump set consist of one E-motor connected to two axial piston pumps with variable displacement and pressure control (P103, P104). The pressure compensators limit the pressure of the pump to approximately 33bar, which is the minimum pressure for accurate swash plate control.

With directional control valves 710Y60, 720Y60 (enable valves) it is possible to increase the pressure control setting of each pump set to the setting of the external pressure relief valve (V112). The pressure setting of the relief valve is 300bar. It is allowed to activate the pressure enable valves when the E-motor switches are switched from star to delta.

he pressure of the main system is monitored and can be read at electronic pressure switch (710B40, 720B40). In case of a malfunction of the pump control the pump is protected against high pressure by pressure relief valves (V122). The pressure setting of the valve will not be reached in the normal operating mode. Check valves (V123) prevent back-flow in the direction of the pumps.

Dirt indicators (710B21, 710B22, 720B21 and 720B22) with a magnet are mounted in the K1-port of the pumps to monitor the drain oil. The indicator will detect if the drain oil contains steel parts. Steel parts on the magnet could be an indication of serious damage on the pump.

The case of the pumps is flushed with oil from the cooling and circulation system. Case pressure can be read by connecting a pressure gauge on the minimess connection on the drain oil connection.

The main pumps are immediately stopped and may not be started when the suction valve is closed.

Start condition Main Pumps	
Cooling pump	Running
Suction valve	Open
Emergency stop	Not activated
Tank level	Not Too Low or Too High

Start sequence Main Pumps	
Start motor	Wait until running contact + 10 seconds
Activate pressure enable	Wait 30 seconds
Check high pressure	System OK

Stop sequence Main Pumps	
Deactivate pressure enable	Wait 10 seconds
Stop E-motor	System stopped

3.2.3.2 Filtration

Filters (Z121) protect the system for 'large' particles. This filter is not used to filter the oil to the specified cleanliness. The maximum pressure drop over the filter element of this filter is 210bar. There is no by-pass valve in these filters. The optical dirt indicators switch at a pressure drop of 5bar.

3.2.3.3 Conditioning

Hydraulic accumulators (Z130) are connected to the HP system to reduce pressure oscillations and to assist the pumps in case of short high flow demands. The accumulators can be isolated and drained with the accumulator safety block (V131, V131). The pressure relief valve in the safety block protects the accumulator against too high pressure when the accumulator is isolated from the main system. Ball valve (V016) can be used to drain the HP system.

Main system alarms		
Sensor	E-codes	Action
Too low main pressure main pump 1	710B40	Stop all main pumps
Too low main pressure main pump 2	720B40	Stop all main pumps

'Dirty' drain oil main pump 1	710B21, 710B21	Alarm
'Dirty' drain oil main pump 2	720B21, 720B21	Alarm
Suction valve pump set 1 closed	710B70	Stop main pump 1, not allowed to start main pump 1
Suction valve pump set 2 closed	720B70	Stop main pump 2, not allowed to start main pump 2

3.2.4 Cooling and filtration system

The cooling and filtration system is used to provide clean oil in the required temperature range.

3.2.4.1 Pump

Screw pumps (P201) are used in the cooling and filtration circuit. The pump is provided with an internal relief valve with a fixed setting of 5bar. Check valves (V010) prevent backflow through the pumps. The butterfly valves (V015) in the suction lines have switches that detect the open position. When the valve is not open, the cooling pump has to be stopped immediately and may not start.

There are two cooling pumps available, only one is running. It is not allowed to use both cooling pumps at the same time. The additional cooling pump is required for redundancy.

3.2.4.2 Cooling

On the HPU frame an oil-water plate cooler Z209 is mounted. The cooling water is provided by the ships LT cooling system. The water inlet temperature is between 35 and 38 degrees. In this way a minimum oil temperature around 40 degrees is provided.

3.2.4.3 Filtration

Tank top filter (Z213), with a 5µm element, filters the oil coming out of the "dirty" part of the reservoir, going to the "clean" part. Filter Z213 has an optical and electrical clogging indicator indicating a pressure drop over the filter of 2bar. The built-in bypass valve opens when the pressure drop over the filter is 3bar.

3.2.4.4 Flushing

The bearing of the main pumps is flushed from the cooling and filtration system. In this way it is guaranteed that the pump housing is full of oil and at operation temperature when the pumps are started. The flushing oil flows through the flushing filter Z206. The flushing filter has visual indication at 5bar and has no bypass valve.

Cooling and filtration circuit alarm		
Sensor	E-codes	Action
Suction cooling pump 1 closed	741B70	Stop cooling pump 1, not allowed to start cooling pump
Suction cooling pump 2 closed	742B70	Stop cooling pump 2, not allowed to start cooling pump
Filter cooling circuit 'dirty'	741B40	Alarm
Cooling pump 1 running	741M1	Not allowed to start cooling pump 2
Cooling pump 2 running	742M1	Not allowed to start cooling pump 1

3.3 HEAVE COMPENSATION SYSTEM (HCS)

3.3.1 Introduction

Reference drawings:

- | | |
|--|--|
| ■ A05-73350-80-00: One line diagram | ■ A05-73350-80-31: Hydraulic diagram (PVU) |
| ■ A05-73350-80-10: Hydraulic diagram general | ■ A05-73350-80-40: Hydraulic diagram (PIU) |
| ■ A05-73350-80-20: Hydraulic diagram (AHC) | ■ A05-73350-80-30: Hydraulic diagram (PVU) |

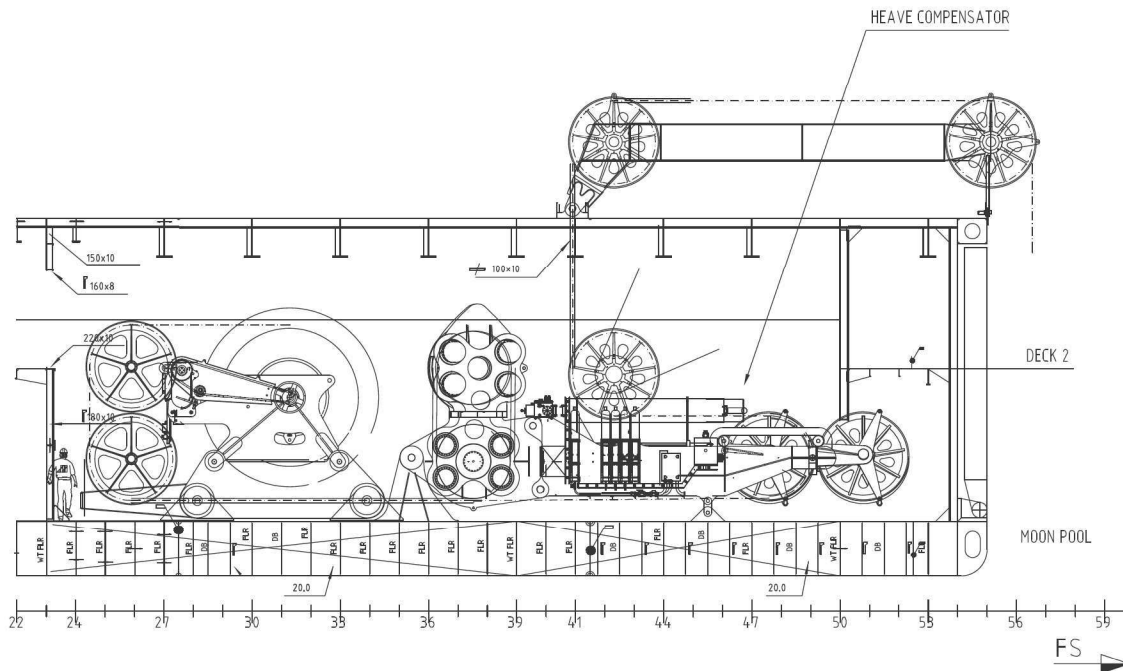


Figure 3-2: Location of heave compensator system

This document contains the hydraulic description of the heave compensator system. The hydraulic system of the heave compensator includes:

- The heave compensator with passive and active manifold (HC)
- The pressure vessel unit (PVU)
- The pressure intensifier unit (PIU)

The primary objective of the hydro-pneumatic heave control system is to reduce the vertical motion of the main block relative to the seabed. The hydro-pneumatic heave control system is operated in one out of three of the following operational modes:

1. Idle mode.
2. Passive Heave Compensation (PHC-) mode
3. Active Heave Compensation (AHC-) mode

In the AHC-mode the main hook is remained in position by active control of the piston position of the compensator cylinder. In the PHC-mode the piston of the compensator cylinder is actuated by variations in the rope force due to drag forces that are exerted on the load. In Idle mode the piston of the compensator cylinder is blocked. Idle mode is an operational state in which the system is not operated in AHC-mode nor in PHC-mode. In Idle mode the system is waiting for operation or prepared for operation.

The set-up of the gas pressure vessels and the hydraulic compensator can be done in each one of the operational modes.

3.3.2 System description

3.3.2.1 Passive and Active heave compensator

The heave compensator consists of one passive main cylinder (A150) and two active auxiliary cylinders (A160) at both sides of the main cylinder. The cylinders are with their bottom ends connected to the traction winch and with their rod and to the head frame with sheave. The bottom compartment of the main cylinder can be connected to the PVU with the passive manifold (M100). Normally the pushing force of the passive cylinder takes the static load on the system.

The force required for the compensation movement is added to the system by the pushing force of the active cylinders and the pulling force of the main cylinder. The active cylinders are single acting cylinders, therefore they only add a pushing force to the system. Both active cylinders and the rod compartment of the passive cylinders are connected to the active manifold (M070).

The position of the head frame with sheave is measured with two length sensors, (941B71, 941B72) the speed of the head frame with sheave is determined in the PLC from the position sensor signal.

The hydraulic system and the gas system of the heave compensator are connected in the medium separator (Z170). The medium separator is a large piston accumulator, the oil side is connected to the passive manifold (M100) and the gas side is connected to the PVU. The position of the piston is measured with a position sensor (945B71) which is mounted in the gas compartment of the medium separator.

Passive manifold

The passive manifold (M100) is mounted between the passive main cylinder (1.50) and the medium separator (Z170). The functions of the passive manifold are:

- connect/disconnect the PVU to the heave compensator
- set up of the position of the main passive cylinder
- set up of the piston position of the medium separator
- pressure relief of bottom compartment passive main cylinder

The bottom side of the main cylinder is connected to the medium separator with the main valves which are two cartridge valves (V120). The position of the valve is monitored with two switches, one for the open position (943B71-1, 943B72-1) and one for the closed position (943B71-2, 943B72-2). The main valves are operated with a seated directional control valve (V121). As the main valve is operated, the valve will remain its position during an emergency stop or a power failure. This is ensured due the electrical system. The pilot oil is taken from the P-line, the medium separator or the bottom part of the passive main cylinder. Interconnecting of the pilot lines is prevented with check valves (V125). The opening and closing speed of the main valve can be adjusted with throttle/check valves (V122, V123).

The cylinder and separator fill/empty valves are two directional control valves (V130, V140). With the cylinder fill/empty valves the bottom side of the main cylinder can be filled and drained, also changing the position of the cylinder (when the main valve is closed) is possible. With the separator fill/empty valves the hydraulic side of the separator can be filled or drained, changing the position of the piston in the separator (when the main valves are closed). The fill/empty flow can be adjusted with throttle/check valves (V132, V133, V142 and V143). Leak free closure of the cylinder and separator is provided by two pilot operated check valves (V131 and V141).

It is possible to manually fill or empty the passive main cylinder with a needle valve (V101A) and to manually equalize the pressure between the bottom compartment of the main cylinder and the medium separator also with a needle valve (V101B). Normally these valves are closed.

The pressure in the bottom compartment of the main cylinder is limited with a cartridge pressure relief valve (V115, V116 and V117). The pressure in the passive main cylinder and the medium separator is measured with pressure sensors (V110).

Normally the heave compensators cylinders are retracted in order to protect the rod surfaces.

Active manifold

The active manifold (M070) controls the movement of the heave compensator in active heave compensation mode and provides boost pressure to the cylinders in passive heave compensation or idle mode. The A and B ports of the manifold are connected to the rod compartment of the passive main cylinder and the active cylinders. Without any valve actuated, the A and B ports of the manifold are interconnected.

Boost system

The boost pressure is provided via the P-port of the manifold. The boost pressure is reduced to 140 bar by a 3-way reducing valve (V0961). Leakage from the cylinders to the P-port is prevented by a check valve (V962). The boost pressure is connected to the A and B port of the manifold with two normally opened 2/2 seated directional valves (V0963, V0964). The small volume difference between the rod compartment of the passive cylinder and the active cylinders is compensated by a 50ltr bladder accumulator (Z082). The boost pressure is monitored with a pressure sensor (944B42). It is possible to release the boost pressure for maintenance with a ball valve (V081), this valve is normally closed.

Servo valves

The servo valves (V093) control the flow to the cylinders. The servo valves are pilot operated servo-proportional valves with a high accuracy. The pilot oil is supplied from the P-port of the manifold. The pilot oil is filtered by a small pressure filter (F092). The filter has a bypass valve and an optical contamination indicator. In order to achieve a constant pilot pressure a diaphragm accumulator (V083) is connected to the pilot circuit. The pilot pressure is measured with a pressure sensor.

A-line and B-line valves

The A-line and B-line valves (V071) are used to disconnect the servo valves from the cylinders. The valves are cartridge valves with a separate pilot valve. The closed position of the valves is indicated with a switch (944B21, 944B72). The A-line and B-line valves are both operated with one seated 3/2 directional control valve (V073). The valves are opened by activating the directional control valve. The pilot oil is taken from either the boost pressure via check valve (V097A) or directly from the P-port of the manifold via check valve (V097B). The opening and closing speed of the cylinder adjusted with throttle/check valves (V072 and V074).

Check and pressure relief vales

The pressure in the heave cylinders is limited with two pressure relief valves (V080). The A-line relief valve is connected to the B-line with check valve (V090) and the B-line relief valve is connected to the A-line. The relief valves are cross-connected in order to prevent a vacuum in the opposite line when a pressure relief valve is opened.

Free-wheel valves

Two free-wheel valves (free-wheel (V075, V076, V077) and slow free-wheel (V079)) connects the A-port and the B-port. The free-wheel valves are normally opened. The flow through the slow free-wheel valve can be adjusted with an adjustable throttle valve (V078). The free-wheel valve (V075) is controlled with a pilot valve (V077). Pilot oil is taken from the A-line, the B-line or directly from the P-port via a check valve (V086).

The P line of the active manifold is connected to four additional bladder accumulators (Z060) to supply additional oil to the system during short high flow demands. The accumulators can disconnected from the system with a ball valve (V061). A relief valve (V063) is placed to prevent too high pressure due to thermal expansion and a small ball valve (V062) can be used to drain the accumulators

3.3.2.2 Pressure Vessel Unit

The N2 gas pressure system consists of 21 individual vessels, each with a capacity of 500 dm³. These vessels are combined into 10 sets of 1000 dm³ each and on storage set of 500dm³ as shown. Each set of 1000 dm³ can be connected to or disconnected from the medium separator with the separator valves.

The individual pressure vessel sections can be re-charged or drained to different gas pressures with the Pressure Intensifier Unit. Each vessel section can be connected to the PIU by remote operated ball valves.

Pressure vessel sections

On each pressure vessel (V060) a manifold (V001) is mounted. On each manifold is mounted a gas pressure relief valve (V002) and a pressure sensor (V061). The separator valves (V010) are directly mounted on the manifold and connect the vessels sections to the medium separator. At the bottom side of each pressure vessel a drain valve is mounted (V004).

Each vessel section can be connected to the high pressure port of the PIU with the high pressure line (HP) and to the low pressure port with the low pressure line (LP). The vessel sections can be disconnected from the LP an HP line with a manual operated shut off valve (V003). These valves are normally opened and can be used to disconnect a vessel section from the system. During operation the hydraulic operated HP and LP ball valves (V020) are used to connect or disconnect a vessel section to the PIU.

Hydraulic operated ball valves

The separator valves (V010) and HP and LP line (V020) valves are hydraulic actuated with directional control valves. A separate pilot circuit is used to supply oil to the pilot valves, which is provided by manifold (M030). The pressure is reduced to 200bar from the main system with a reducing valve (V031) and limited with a pressure relief valve (V032). A check valve (V034) pre-

vents leakage from the pilot circuit in case of a power failure. The bladder accumulator (Z053) makes it possible to switch several ball valves after a power failure. The bladder accumulator can be disconnected from the system with an accumulator safety block (V055). The pressure of the main system and the pilot circuit can be read from pressure gauges (Z062 and Z063)

The separator valves are controlled by 4/3 directional control valves (V012). The separator valves are controlled by two solenoids, one for each position. As the separator valves are equipped with a mechanical lock, the solenoids only must remain energized until the newly requested position is detected. Both the open and closed position of the ball valves is detected with a switch.

The HP and LP ball valves are controlled with 4/2 directional control valves (V021). The HP and LP ball valves are opened as long as the pilot valves are actuated. Both the open and closed position of the ball valves is detected with a switch.

3.3.2.3 Pressure Intensifier Unit

The heave compensator system is equipped with a PIU to charge gas into a selected vessel section. The intensifier consists of 2 stages; a high pressure stage and a low pressure stage. The first stage unit can be driven by two separate compartments, C1 and C2. The second stage unit is driven by a single compartment C3.

Manifolds

The strokes of the PIU are controlled by a pilot operated 4/2 directional control valve, the "stroke control valve" (V203A). This valve is mounted on a manifold (V201) together with two flow control valves which controls the cycle time of the compressor. Pressure compensated flow control valve (V205) controls the speed of the return stroke of the high pressure stage C3 (return means pushed back by gas pressure). Pressure compensated flow control valve (V214) controls both the speed of the pressure strokes of the high pressure stage (B-port) and the low pressure stages (A-port) of the PIU.

The A-port of the stroke control valve is connected to manifold (V202), which is used to disable C1 or C2. If both disable valves (V203B, V203C) are deactivated, both C1 and C2 are used. Pressure compensated flow control valves (V204A and V204B) are used to adjust the speed of the return strokes of the low pressure stages C1 and C2. The pressure relief valves (V206) prevent too high pressure when C1 or C2 is disabled. Check valve (V207) prevent a too low pressure in a disabled compartment C1 or C2. Therefore the return pressure is increased to 5bar by a check valve (V211). A piston accumulator (Z208) is used to maintain this pressure during the full stroke of the low pressure stage. Ball valve (V210) can be used to disconnect the PIU from the system for maintenance. Small ball valve (V212) can be used release the piston accumulator (Z208).

Pressure Intensifier Cylinders

The PIU is connected to the HP and LP lines of the PVU with ball valves (V003). The cylinders have check valves (V220) connected on the inlet and outlet to reduce the clearance volume of the PIU. Between the first and the second stage of the PIU a N2-water cooler is mounted to reduce the inlet temperature of the second stage of the PIU. The pressure intensifier cylinders itself are cooled with a cooling jacket.

The pressure on the inlet and outlet of the PIU is measured with a sensor (798B44, 798B45). The hydraulic pressure in the C1, C2 and C3 compartments is also measured with a sensor (798B41-43). The temperature at the outlet of the PIU to the HP line is measured with a temperature sensor (798B50), a too high temperature indicates a failure of the cooling circuit.

Equalize valve

The equalize valve (V020) connects the HP line with the LP line. The equalize valve is controlled with a 4/2 directional control valve (V013). The equalize valve is opened as long as the pilot valve is actuated. Both the open and closed position of the equalize valve are detected with a switch.

Adjusting the Pressure Intensifier Unit

The single manifold (M201) controls whether the large or small cylinder is activated. By 'activation' is meant that hydraulic oil is fed into the cylinder and nitrogen is compressed.

Normally, the large cylinder is activated. Controlling the valve causes the large cylinder (first step) to retract and the small cylinder to extend. The speed of both cylinders is controlled by a pressure compensated flow control valve (V214). Side A serves the large cylinder, while the small cylinder is served by side B. Turning in the valve reduces the nitrogen compression speed, resulting in a slower extension stroke. In general, the B-side of the valve is turned in a bit further than the A-side, because of the smaller piston area of the small cylinder, requiring a lower oil flow.

The other manifold (M202) is used to disable either of the two compartments of the large cylinder. Depending on the pressure at the suction side of the gas pump (LP), either C1 or C1 is used, or both. The pressure compensated flow control valves at this manifold (V204) are used to set the suction stroke of the pump. The piston retracts by nitrogen pressure, and by setting the flow control valve the pump speed is varied.

Both cylinder compartments are mechanically connected, which requires the flow control valves to be set so that during the suction stroke the pressure in both compartments is about equal.

NOTE *This applies only when both C1 and C2 are used.*

As a rule, these valves are already preset correctly. The speed of the suction stroke of the small cylinder is controlled by valve V205, which is also correctly preset.

CAUTION



When adjusting the flow control valves at the double manifold (M202), be careful not to adjust the pressure safeties (V206)!

Valve V214 may require some fine-tuning. Basically, all stages of the cycle must be equal. If C1 and C2 are both used (LP>45bar), the PIU runs at 5 or 6 cycles per minute. If only C1 or C2 is used, the PIU can cycle at a higher rate.

WARNING



Carefully watch the temperature in the HP-line. In case of a high pressure ratio of the pump (high HP and low LP), the temperature may rise considerably!

3.3.3 Functional description

3.3.3.1 Start Powerpack

Start filter pump

Start electric motor (743M1) of filter pump. Pump may only start if:

- Suction valve is open (V014B)
- Return valve is open (V014A)

Start cooling pump

Start electric motor (741M1) of cooling pump. Pump may only start if:

- Suction valve is open (V015A + V015B)

Start main pump

3 seconds after pushing the start button, the start sequence will begin.

Start electric motor (710M1/720M1) of main pumps. In operation both main pumps may be running. Pumps may only start if:

- Suction valves open (V011A + V011B)
- Oil temperature NOT too low $> 30^{\circ}\text{C}$ (730B50)
- Oil temperature NOT high $< 65^{\circ}\text{C}$ (730B50)
- Oil level NOT too low (730B74)
- Oil level NOT too high (730B71)
- Cooling pump NOT running

Enable pressure (710V111/711V211) after star/delta sequence. Main pumps are running at 280 bar.

3.3.3.2 Stop Powerpack

Stop main pump

5 seconds after pressure is disabled, stop electric motors (710M1/720M1) of main pumps.

Stop cooling pump

Stop electric motor (741M1) of cooling pump.

Stop filter pump

Stop electric motor (743M1) of filter pump.

3.3.4 Alarms

Main pump

Stop main pumps if:

- Emergency stop active

- Suction valves (V011A + V011B) are NOT open
- Oil level too low
- Oil level too high
- Oil pressure too low
- High temperature of electric motors >140°C

Generate alarm (no stop) if:

- Main pump contaminated (710B21 / 710B22 / 720B21 / 720B22)
- High temperature of electric motors >120°C

Cooling pump

Stop cooling pump if:

- Suction valve (V015) is NOT open
- Oil level too low
- Oil level too high
- E-stop

Filter pump

Stop filter pump if:

- E-stop

4 ELECTRICAL DESCRIPTION

4.1 INTRODUCTION

This chapter provides a general description of the electrical installation of the 300t DWLS

The electrical system

- Power distribution
- Control of all movements
- Reverse power handling

4.2 ENERGY SUPPLY AND POWER DISTRIBUTION

has two ships electrical rooms, which are situated in the hold on the port and starboard side of the 300 mT DWLS system. Each switchboard supplies one HPU motor and one 12 pulse transformer which in turn supplies the DC rectifiers. The starboard ships switchboard room contains also the POCA cabinets for the . winch and crane system. The crane is supplied by the same two independent DC supplies and 440 Vac 60 Hz.

is fed from two 3 x 440 Vac 60 Hz ships supply. Two 12 pulse transformers and four rectifiers are used to make the DC voltage for the drives. The two DC rails can be connected by an emergency link if a charging rectifier and/or a 12 pulse transformer is out of service (system operates at 50 % power then). The two 930 Vdc rails are used to supply the electrical drive system of the traction winch, storage winch

The two DC rails are supplied by two 12 pulse transformers, which are each supplied from their own switchboard, situated on the port and starboard side of the 300 mT DWLS system

Two water cooled brake resistors (700 kW each) are supplied for the 300 mT DWLS.

During lowering of the load the energy is dissipated by the water-cooled brake resistors via the brake chopper. Peaks during crane operations (lowering) can be dissipated by the air-cooled brake resistors.

Another six 440 Vac 60 Hz ships supplies are used for the HPU pumps, POCA cabinet of the crane and POCA cabinet of the 300 mT DWLS.

The ships chief electrician/engineer has the possibility to choose if the POCA supply comes from the port side or the starboard side by selecting the various AC cross connections in the ships mains.

The hydraulic power unit (2x 400kW) is energized from two separate 440 Vac 60 Hz supplies, one from port and one from starboard.

The 230 Vac is supplied to the power and distribution cabinet F20 in the starboard switchboard and also . This 230 Vac supply is also used for several equipment such as cabinet lighting, heating, brakes and other items.

The 230 Vac is also converted to 24 Vdc by a battery charger in F20. The battery is connected via a battery isolation switch which is located directly at the left side of the battery box. This supply to the ELCA's is partly used for several PLC modules and sensors

outfitted with two UPS systems, one for the 300 mT DWLS). These UPS systems feeds the essential equipment, in case of a power failure. These essential equipment:

- PLC
- E-stop circuits
- Emergency lightning

4.3 DRIVE SYSTEM

4.3.1 Electrical - Hydraulic drives

Two electrical motors are used for the main pumps in the hydraulic system, these motors can operate parallel. This is decided by the operator, and depends on the amount of heave that needs to be compensated.

Two small electrical pumps are used for cooling. Only one pump may be running at a time. During start up of the main pumps it is necessary to have a cooling pump running. This is because the cooling pump will make sure the main pump is filled with oil prior to running the main pump.

A third motor is used for filtering the oil. It is advised to keep this pump running at all times. More info in the CD folder "Supplier documentation", /Hydac.

4.3.2 Electrical drive

4.3.2.1 DC supply system

The DC-bus consist of two separate bus rails.

They are supplied from the port and starboard ships mains power. Both DC buses are necessary for operation of the 300 mT DWLS winch or crane.

Inside the crane 2 switches are provided to isolate the crane from the DC supplies.

One DC rail is supplied by the port ships AC switchboard and one supplied by the AC starboard ships supply. These ships AC switchboard can be interconnected. (see the ships manual)

Each bus rail is provided with a charge circuit. Resistor based charge circuits are used for the crane and coil base charge circuits are used for the 300 mT DWLS system. The purpose of the charge system is limiting the chargeing current at switching on the DC rectifiers. If the DC bus voltage rises too quick damage may occur to the capacitors fitted in the inverter drives.

The port and starboard DC bus can be connected in case of failure of one rectifier or 12 pulse transformer. This can be done by two copper rails located in the centre of C11. It is important to follow the procedure described in "warning" at page 52 before connecting the DC bus / emergency connections.

The available power will be 50 % of normal, but running crane or 300 mT winch one at a time will be no problem. If high loads are handled with the 300 mT winch , the speed needs to be reduced.

DC pre-charge system

Charging is controlled by a Zelio PLC, which detects if the DC voltage is high enough to activate the main contactor (bypass for the charging system). It also has some safety detections that can generate the following fault messages on the display of the Zelio 61A11 and 61A31:

Fault Restart timer	Trying to restart while timer (6s) is not ready
Fault Total start time	Start not completed in 20s
Fault DC bus	DC bus < 900V, while bypassed

Fault Precharge contactor
Fault Bypass contactor
Fault bus too high

Precharge contactor not active within 100ms
Bypass contactor not active within 300ms
DC bus > 1180V during loading

The following checks are available in the program but disabled:

Fault Not loading

DC bus < 872V after 25s (Disabled)

Fault Starting loading
relays (Disabled)

DC bus < 100V after 20s after contactor load

The only alarm displayed at bridge SCADA will be:

- DC supply circuit 1 Fault (Starboard)

or

- DC supply circuit 2 Fault (Port)

When the DC bus is charged a status "OK" is send by each Zelio PLC for DC rail 1 and DC rail 2.

If one of the rectifiers has failed it is possible to use only one rectifier at maximum 500kVA. The emergency link has to be put in place. This is detected by the system. For purposes of safety interlocks with rectifiers, but it is the operators responsibility to limit the power. The rectifier is only protected by fuses and temperature measurement.

It is necessary to switch of one of the DC bus earth leakage detection units as they will interfere with each other causing failure messages.

WARNING



It is necessary to switch off one of the DC bus earth leakage detection units as they will interfere with each other causing failure messages.

Safe working on DC bus

For maintenance en repair: The voltage on the DC bus can be switched off by the PLC/SCADA system. In order to ensure that the voltage is not turned on again, the protection switch(es) 61Q10 and 61Q20 locked out mechanically by switching them to "off" and then pulling out the locking tag.

For extra security it is advised to disconnect and lock both 440 Vac breakers, in the port and starboard ships switchboard that supply the 690VAC transformers.

The DC bus must be grounded on both positive and negative side, during maintenance at the DC.

Also, the Bender earth fault detection units -61A12 and -61A32 must be switched off as it also puts a 50V on the DC bus.

WARNING



Before switching on DC in linked mode it is necessary to keep one of the Bender units off as they will interfere with each other causing erratic failures.

WARNING

Be careful before opening any cabinet with inverters or rectifiers! after switching the power off, it will take several minutes before the voltage on the copper rails is safe!

WARNING

Apart from waiting several minutes before opening the cabinet after switching, check the voltmeters mounted on the first cabinet to verify if the voltage is zero!

Frequency inverters

The only right way of controlling an induction motor for hoist applications is to use speed control with feedback from an encoder fitted to the motor.

As standard squirrel cage induction motors are designed to be used at one speed only, the shaft driven cooling fan is designed for an airflow which will cool the motor adequately under full load at rated speed. When using a frequency inverter, the speed can be varied and therefore also the cooling fan will have less flow. The standard fan is a centrifugal type fan which will hardly produce any airflow below 30% speed.

The heat production of the motor is partly proportional to the motor current (or motor torque) and partly proportional to the motor speed. The heat loss produced by the resistance of the motor windings is only dependent on the motor current. The heat loss produced by the iron magnetization changes, is proportional to current multiplied by motor speed.

Therefore, a standard induction motor can generally be used at low speed (10%) for unlimited time as long as the motor torque is less than approximately 80%.

In crane applications however, the torque is determined by the load, which is the same in low and high speed. This means that there is some limitation to the use of a crane with standard AC induction motors. This limit however will hardly ever be reached during normal use. This is because the duty cycle of normal crane operation is very low. Since the hoist movement can never be used for unlimited time, the motor will always have time to cool down again. The actual hoisting time (with full load) in practice is only around 15 to 20%. The motors do have thermistors inside, if the limit of the normal crane operation is exceeded it generates more heat. The thermistors are connected with the PLC. Extra cooling fans are placed at the motors.

Another specific characteristic of a frequency controlled drive system is the possibility to extend the operational speed above the rated speed of the motor. By increasing the frequency above the rated motor frequency, the motor speed can be increased up to the mechanical speed limit of the motor.

The available motor torque will decrease in this case, so high speed (or field weakening) can only be used with partial load of the drive system. In order to guarantee a safe crane operation, field weakening is only allowed when the load protection system has detected a low load. This detection is "fail safe", meaning that in case of a broken connection of the load measuring sensor or a fault in the load protection computer system, the frequency controller will not be allowed to accelerate the motor above the motor rated speed.

The frequency inverter has several functions:

- control of motor speed
- control of lifting mechanical brake

- control of motor in case of a slipping brake situation

A slipping brake is detected as the drive detects that the motor is rotating while the brakes are engaged. If this happens the drive will force the motor to zero speed according to the shaft encoder. At the same time the drive will issue a slipping brake alarm to the PLC in order to alarm the operator. If this happens the operator will need to bring the affected function to a safe position - such as putting the load on deck, lay the boom in its cradle - BEFORE stopping the crane.

WARNING



Before removing I/O boards from the control unit of the inverter the 24V supply must be turned off! For the inverter control boards there is a 24V supplies: a separate 24V supply from the electronic cabinet. It must be turned off before removing I/O boards!

E-Motor

The choice for a particular type of the asynchronous squirrel cage induction motor is based on calculations. In these calculations the inertia of motor and load, and the desired speed and force are used. Once the right motor is selected, important features are the start up current, power and rpm of the motor.

For each drive system the most important part is the start and stop cycle which includes the brake control.

Brake control

All motors for driving the winches are equipped with Pintsch Bamag brakes. All brakes are static brakes. When you start a movement, first the inverter will build up the required torque to hold the load, then the brakes are released. After the brakes are released the motor may accelerate. When you stop a movement, the inverter will actively force the speed to zero after which the brakes will apply.

At the moment the drive is on and in standby, the drive will generate a 4% torque against the brakes. This is done in order to keep the motor magnetised, which will enable a quick start of a movement.

On the backside of the motors brakes are placed. However, the brake resides between the gearbox and motor in case of the main hoist and luffing motor. These brakes are electrically controlled. A voltage of 65V dc to the coils of the brake will keep the brakes lifted. When the brakes are lifted, for a short moment a higher voltage will be applied. The brake will close immediately when no voltage is applied.

Speed control

The motor speed is controlled by the inverter by varying the frequency and voltage to the motors using vector control.

Cooling

Most motors use external cooling, which enables to apply 100 % torque at 100 % of the time without overheating the motor windings.

Brake resistors

When reverse energy is generated it can be handled in two ways. The most used option is to feed this energy back into the vessel power plant. However, this option is not always possible. For example when the vessel power plant is not capable of handling this reverse energy.

The second option is to get rid of the reverse energy by means of resistors. During de-acceleration or lowering, reverse energy is generated, which can damage the electrical system. To prevent this, the created energy must be removed from the system. The reverse energy is fed to the brake resistors via a brake inverter, configured as a brake chopper. Each brake chopper is protected by a slow fuse. This reverse energy will produce heat in the resistors which in turn are cooled by cooling water pumps.

The water flow through both resistors and water temperature outlets are monitored by the PLC. The flow and operation of the fresh water pump and sea water pump is not controlled and checked by the PLC. The ship's board provides a standby function which will make sure that if a port side pump fails, its starboard counterpart will take over and vice versa.

A warning is given if one of the brake resistor temperatures is not OK. The DC system will shut down consequently. Without DC system the crane as well as the 300 mT winch system will be out of operation.

PLC

The heart of the electrical system is the winch PLC which is placed in the ELCA F40, the heave PLC is located in the ELCA F60. The third PLC is located in the crane ELCA. The crane, winch and heave PLC's, as well as all SCADA stations are interconnected by ethernet. The winch PLC and heave PLC are interconnected also by profibus.

The PLC's are connected to the remote IO stations by profibus cables.

Two fiberlinks provide the Ethernet link between the vessel bridge and all PLC's and SCADA stations.

At the bridge a SCADA monitor, CANBUS-drive and I/O station is located. A satellite connection can be built up through the HUB at the bridge I/O station.

The CAN bus can be used to monitor the drives of the 300 mT DWLS system.

The satellite connection can offer access to all PLC's in case of problems that can not be solved on board. The SCADA station on the bridge is equipped with the software needed to perform remote PLC access.

Explanation of operation & control is described in Section 5: "Operation" on page 85.

4.3.2.2 Description and Points of Attention: Inverters

Vacon inverters are used to drive the motors of the winches. See the supplier documentation for more information on the inverters.

WARNING

Before removing I/O boards from the control unit of the inverter the 24V supply must be turned off! For the inverter control boards there are two different 24V supplies: a 24V supply derived from the DC bus and a separate 24V supply from the electronic cabinet. Both must be turned off before removing I/O boards!

WARNING

Before removing the motor cables (also on the motor side) the DC voltage must be turned off! Fuses can also be removed, but then also power must be off from the DC bus.

WARNING

It is recommended to have the fans of the Vacon drives turned on when the DC power is turned on.

4.3.2.3 Description and Points of Attention: Brake resistors

The resistor stages are connected to the DC bus by the two brake inverters as soon as the voltage is higher than a 1017 Vdc as the voltage rises the current will increase to 325A at a voltage of 1050 Vdc.

The resistors are placed in two cooling vessels. Water flows through both vessels. The resistor elements connected to one brake inverter (and one DC bus) are placed in one vessel. On each resistor vessel the temperature of three of the resistor elements is measured. The fresh water flow and temperature are measured and supervised on each vessel.

In the junction box of the resistorbank a humidity sensor is mounted and the cabinet is equipped with a heater.

WARNING

Keep the heater on to avoid humidity near the elements, as the insulations in the elements is hygroscopic.

The resistor bank is designed for a fresh water flow of 85 m³/hour per vessel. At maximum power this will result in max 4°C increase in water temperature. The resulting element temperature will then be 45°C. When contamination is on the elements the temperature of the elements can increase to 58°C. When higher temperatures are measured the resistor bank should be cleaned. It is recommended to clean the system every year.

In practice a flow of 68 m³/hour per vessel shall be used. This results in max 10°C increase in water temperature at maximum power. Then above mentioned element temperatures should be increased with 6°C.

The fresh water flow to each vessel is measured by a Kobold flow sensor (KAL AK5415AS). This sensor measures the water speed (**2m/s equals 20mA = 100%; if not adjusted!**).

Assuming that the outlet has a 4" diameter, then 68 m³/h of seawater equals 2.3m/s, which is 116% on the reading.

Warnings/Protection

For each resistorbank vessel the following is measured:

- The temperature of 3 resistor elements
- Output water temperature
- Water flow
- Humidity sensor (only warning).

The complete system must be stopped if only 1 brake inverter / resistor bank is active and if:

- resistor element temperature is higher than 70 °C or
- output water temperature is higher than 60 °C or
- water flow is below 25%.

NOTE	<i>The humidity sensor is set at 70%, and only gives a warning.</i>
NOTE	<i>A warning is given if the element temperature is higher than 60°C, indicating that the resistor bank should be cleaned.</i>
NOTE	<i>The heater in the resistor bank E-cabinet must always be powered and filled with silicon gel to avoid humidity in the cabinet.</i>
NOTE	<i>For each temperature sensor a spare sensor is available. Watch that you use the right sensor as they are connected to elements belonging to different stages.</i>
NOTE	<i>For further information see the supplier documentation (Sinus Jevi).</i>

WARNING

It is recommended to have the fans of the Vacon drives turned on when the DC power is turned on.

Brake chopper

In the crane, two chopper and air cooled resistors are installed. It is meant to limit the DC-bus voltage in case it gets too high due to dynamic operation. It is not meant to operate continuously.

The brake chopper can dissipate 67kW of energy for a short period of time and 12.5kW continuously. The chopping voltage should be set as high as possible (1100V).

The status of the brake chopper and the brake resistor temperature is fed back to the PLC. A warning is given if the brake chopper is not OK or if the brake resistor temperature is not OK.

4.4 MISCELLANEOUS ELECTRICAL COMPONENTS

4.4.1 Brakes

The inverter informs the PLC via the profibus when the inverter gives the command to release the brake(s). On each brake a proximity switch detects whether the brake is released or not. The signal from the proximity switch is sent to the PLC. With these two signals the PLC can check the status of the brakes. When the inverter sends the signal "Brake release" to the PLC and within 1 second (approx: value varies per function, see PLC program) the proximity switch is activated, the PLC knows that the brakes are released.

If the proximity switch is not activated in 1 second, the alarm "Brake Release failure" is given. The PLC immediately disables the move command. If all the brakes are released and the inverter deactivates the signal "Brakes release" to the PLC, the PLC must also see the proximity switch signals deactivate in 1 second. If not, the PLC will give an alarm: "Brake Apply Failure". The PLC sends the speed setpoint to the drives after it has detected that indeed all brakes for that movement are released.

"Slipping brake" is an alarm the inverter sends to the PLC via the profibus. A slipping brake alarm occurs when the inverter detects that the motor rotates while the inverter does not release the brake. This slipping brake detection is only possible when the inverter is active. When slipping brake occurs, the inverter will apply torque in order to force the movement to stop automatically.

WARNING

At that moment it is not advised to de-activate the inverter or the rectifiers (or apply the emergency stop) because the inverter would then loose control over the winch. In such situation the operator should move the crane to a safe position before switching off the crane or applying emergency stop. In case of a hoist movement it is advised to put the load on deck, in case of a luffing movement: Put the boom in its boom rest, before switching off the crane and check the brakes.

There are three contacts in series which all must be activated to lift the brakes.

- A PLC contact. This contact depends on whether the inverter is active and has no fault or if there is an external reason to make a crash stop.
- An DISPS contact. The DISPS can release the brakes depending on its settings normally only overspeed is programmed into the DISPS.
- An inverter contact. This is directly controlled by the inverter.

4.4.2 Digital Independent Speed Protection System (DISPS)

On each winch an independent shaft encoder is mounted inside the geared cam switch housing which is connected with the DISPS card. The DISPS measures the speed and compares this value with the maximum allowed speed. If the speed is too high, the DISPS will de-activate the relay in the brake circuit and the brakes will apply. A failure in the shaft encoder will also give a stop. The PLC also detects if the DISPS de-activates the relay.

DISPS is available on:

- Both drums of the traction winch
- Mainhoist winch
- Luffing winch

The PLC gives a N>X signal to the DISPS if the system is running above a certain speed. The DISPS also detects the speed from the encoder which is located inside the geared cam switch, and thus checks if the winch speed is above the preset speed in the DISPS.

The DISPS can detect two maximum speeds, normal speed and speed at Field Weakening (FW). The DISPS receives actual speed allowed, and a signal from the PLC in order to know which maximum speed is allowed.
ces

An extra hardware feature is that when the emergency stop is active the "DISPS OK" signal is disabled and a contact of this relay is in the reset loop of the emergency stop. Thus the proper working of the relay is checked.

The DISPS is in direct control of the brake for each movement!

4.4.3 Control locations

The local control (traction & storage) can only be activated after communication with the bridge. The local operator has to ask control by pushing the local control button. Then within 30 sec the bridge has to release control. The local control button stops flashing and the local operator can operate the winch. For independent movement of traction and storage winches it is necessary to go into service mode at the bridge SCADA screen. In normal mode it is possible to get local control of the traction winch when the storage winch is in CT mode. Independent movement of the traction drums is only possible using service mode.

NOTE	<i>The voltage in the drive is NOT turned off. Only controls are disabled.</i>
-------------	--

4.4.4 Walk around box

4.4.5 Earth Fault Detection

Each insulated supply has its own earth monitoring system:

- 230V with Bender IR-140-Y-421
- DC-bus with Bender IRDH275B

A warning should be generated if the insulation resistance is below 1MΩ. For the DC-bus a second warning is generated at 100kΩ.

The good operation of the earth fault monitors should be tested regularly. This can be done by creating a high impedance earth fault. An insulated 100kΩ resistance or a Duspole measurement device can be used for this purpose.

NOTE	<i>If the DC-bus is only supplied by rectifier circuit 2 the earth faults in the DC system are NOT monitored. (But before energizing the DC-system the earth faults could be detected.)</i>
-------------	---

The elements in the resistor bank give the system a relatively low insulation resistance (IR). This is because two times 48 elements are placed in parallel. The IR of these elements could vary. Although each has a high IR of hundreds of MegaΩ, the resulting total IR could drop below 10MΩ.

4.4.6 Emergency Stop

The complete system is equipped with several emergency stop systems. The emergency stop system is divided into:

- Normal emergency stop for all winches
- "Passive heave" emergency stop
- Emergency stop for the crane

The emergency circuit is hardwired with double contact emergency relays. See also the complete emergency stop system in E-plan drawings.

Normal emergency stop system

In the normal emergency stop system one (Pilz PNOZXV774502) main relay is used and several (Pilz PNOZX2.774306) auxiliary relays. The main emergency relay is found in cabinet F60. Auxiliary emergency relays are found in the cabinet: +F40.

The emergency system is normally active. It is deactivated by emergency buttons that are placed on locations where the system can be controlled. The emergency buttons are visual the same for the normal and "passive" heave emergency system. However, the impact is different when pushing the button. All emergency stop buttons are monitored by the PLC. The PLC/SCADA can tell which button is pushed. The PLC will stop the system if it detects a pushed button.

The emergency system is also deactivated if the PLC is no longer working. This is detected by a watchdog. If the watchdog is not activated by the PLC within a certain period of time, the main emergency relay is de-activated.

If the emergency relays are deactivated their direct contacts are deactivated and after an adjustable time (often 1s) the delayed contacts are deactivated. The delayed emergency stop is necessary to enable the system to stop in a controlled way.

The emergency relays can only be activated after the reset loop has been closed. This is to check if all safety relays (systems) are indeed activated. The reset loop can be found on the electrical diagrams, on the pages with the emergency relays.

Equipment that is switched off directly by the emergency relay:

- All E-motor cooling fans
- HPU main pump motors (is part of active heave system)
- HPU cooling and filter pump motors
- All hydraulic valves (except the main passive heave valve) and the PVU valves.

Equipment that is switched off with a delay by the emergency relay:

- Inverters
- Motor Brakes
- Active heave will stop because hydraulic valve is disabled.

"Passive heave" emergency stop system

In the "passive heave" emergency stop only one (Pilz PNOZXV2774500) main emergency stop relay is used which is located in cabinet +F40 with aux. emergency relay in +F60.

The heave emergency system is normally active. It is deactivated by special (indicated as "passive heave" emergency stop) emergency buttons that are placed near the heave compensator, the pressure vessel units and on the control desk.

If the "passive" heave emergency relay is deactivated the following happens:

- the main passive heave valve is closed.
- the valves between pressure vessels and separator are actively closed.
- the normal emergency stop system is deactivated.

NOTE	<i>If the 24 Vdc power to the main valve is disabled, the valve will always close.</i>
-------------	--

NOTE	<i>The PVU valves are latching valves. They will only receive a 10 sec closing command which after they will remain closed.</i>
-------------	---

The system is designed such that in heave operations the main passive heave valve will not close due to:

- normal emergency stop
- PLC failure

It will only be closed if:

- it is actively turned off by the PLC
- "passive heave" emergency stop
- failing 24V battery supply

Emergency stop for crane

The mainhoist, luffing and slewing have their own independent emergency stop system. The emergency stop relay (Pilz PNOZXV2774500) is located in cabinet +C13.

The emergency system can only be activated by the emergency stop button in the winch room, slew room, crane cabin or emergency control box +E10, if connected. Because the crane and 300 mT winch system share the same DC supply. The crane E-stop will not switch off the DC supply to the 300 mT winch. Inside the crane POCA the crane DC system will be switched off.

Concluding / Important

- A normal emergency stop stops everything except the passive heave operation.
- A "passive heave" emergency stop stops everything including the passive heave operation.
- Crane E-stop and DWLS E-stop don't interfere.

4.6 300 mT DWLS

Traction Winch

The traction winch consists of two drums, each driven by four motors. Each motor is connected to a planetary gearbox that drives a sprocket which is engaged in internal teeth on the drum bearing at the motor end of the drum. Two motors (145kW) are controlled by one frequency inverter. The inverters are all located in cabinet +C11.

Each motor is equipped with an electrical brake. Three of the four motors of each drum consists of a encoder. Two encoders for the drive system and the other for the DISPS. Each motor is also equipped with cooling fans and heating. The heating is only active when the drive system is turned off. Each motor is also equipped with a thermistor which is monitored by the PLC. The shaft encoder is directly connected to the inverter and enables the inverter to control the motor by means of vector control. To detect if the brakes are lifted or applied each brake is equipped with a 3-wire proximity switch which is directly connected to the PLC.

The winch is protected by DISPS. (digital independent speed protection system) For this protection one of the electric motors is equipped with a shaft encoder that is directly connected to the DISPS. In Section 4.4.2: "Digital Independent Speed Protection System (DISPS)" on page 59 an explanation can be found.

The load is measured at the sheave of the main heave cylinder (see heave system)

For maintenance use, and during reeving in new wire ropes it is possible to operate each single drum from the local control station. In order to do so it is necessary to enable the local control station as well as "service mode" on the bridge SCADA screen. See Section 4.4.3: "Control locations" on page 60.

It is needed to be in service or in manual mode to do so, and also it is needed to transfer control from the bridge to this station. The bridge has to release control and within 30 seconds the operator at the winch need to acknowledge to take control. The same procedure is used to give control back to the bridge. Typically this local control is used for reeving in a new wire on the storage winch. After the first windings are on the storage winch the empty drum switch has to be adjusted. Then CT on the storage can be activated. After that the traction winch local control give full control over the reeving process.

WARNING



After the first windings on the storage winch the empty drum switch has to be adjusted.

Storage winch

The storage winch is driven by two motors. These two motors are connected to a planetary gearbox that drives a sprocket which is engaged in internal teeth on the drum bearing at the motor end of the drum. The two motors (45kW) are controlled by one frequency inverter. The inverter is located in cabinet +C11.

Each motor is equipped with an electrical brake and a shaft encoder at the non-drive end. Each motor is equipped also with cooling fans and heating. The heating is only active when the drive system is turned off. Each motor is also equipped with a thermistor which is monitored by the PLC. The shaft encoder is directly connected to the inverter and enables the inverter to control the drum by means of vector control. To detect if the brakes are lifted or applied each of these brakes is equipped with a 3-wire proximity switch which is directly connected to the PLC.

To safeguard the outer limits each winch is also equipped with a geared cam switch. This switch has six contacts.

- ultimate highnot used
- highThe traction winch slows down to creeping speed
- pre-highThe traction winch slows down to reduced speed
- pre-emptyThe traction winch slows down to reduced speed
- emptyThe traction winch stops, storage remains in CT
- ultimate emptyThe storage winch drops out of CT mode

WARNING**Avoid serious damage:**

During creeping speed attention has to be taken. When passing the "high" position visual observation is necessary. Keep in mind the impact of the heave compensator. Due to the fact there isn't a highest position sensor located at the deckbeam, the hook can be pulled against the deck beam.

Suggestion: De-activate the heave compensation after passing "high" position.

Two Turck sensors are mounted at the storage winch. The measured signals are led to the speed encoder inputs of the PLC. In this way length measurement is implemented.

In the shaft of the lower guide sheave near the storage drum a load cell is situated. This load cell is used to control the tension in the wire between the traction and the storage winch. This loadcell has two independent outputs, one calibrated from 0-120 mTon and one calibrated from 0-30 mTon. The normal CT value is 12 mTon.

The upper guide sheave is equipped with two proximity switches which detect speed and direction of the 106 mm wire.

For maintenance use, and during reeving in new wire ropes it is possible to operate the storage drum from the local control station. See Section 4.4.3: "Control locations" on page 60.

It is needed to be in service mode to do so, and also it is needed to transfer control from the bridge to this station. The bridge has to release control and within 30 seconds the operator at the winch need to acknowledge to take control. The same procedure is used to give control back to the winch. Typically this procedure is used to adjust the initial storage CT which is necessary for CT mode to engage.

The spooling device for the storage winch is of the mechanical drive shaft type and is not connected to the electrical system.

4.7 HPU

E-motor main pumps HPU

The E-motor of the main pump is an ABB squirrel cage motor. The nominal output power is 400kW S1 (100%), which indicates that the motor can deliver 400kW continuously, and per 10 minutes (S6) for 2 minutes (20%) an output power of 500kW. (HPU).

The nominal voltage is 440V (HPU) at a frequency of 60Hz.

The motor is started with a star-delta starter. After the motor is started, it can be loaded.

For further information see the documentation of the main pump motor in the supplier documentation.

The E-motors do have a motor current protection. The E-motors of the main pump contains two thermistors to protect the motor from overheating: Only thermistor 130 degrees is connected to the motor overload relay in the power cabinet.

When the main pump is not used, the standstill heating is switched on to protect the E-motor against condensation and thus the motor windings against corrosion.

Two general Emergency stop buttons are provided on the HPU-frame. They switch off all electrical winch motors and both HPU motors. This stop will NOT affect the main valve of the passive heave compensator.

WARNING



The motor is self cooled, so do not cover the air inlet openings at the top of the motor. This can lead to serious damage due to overheating.

4.8 PASSIVE AND ACTIVE HEAVE SYSTEM

The heave system consists of the following parts:

- PVU consisting of 10 pressure vessels of 1000 liter and one storage vessel of 500 liter. All can handle 300 bar of nitrogen.
- PIU Pressure Intensifying Unit for adjusting the pressures in the PVU's
- Main cylinder with sheave equipped with load cell calibrated 0-450 mTon. This loadcell is used to supervise the load being handled by the 300 mT DWLS system. The load is displayed on the SCADA screen on the bridge.
- Passive manifold which is connected between main cylinder and medium separator. This manifold contains the main valve, and the fill and drain functions for the separator as well as the main cylinder.
- Medium separator. This can be seen as a hydraulic piston without a rod, which is used to separate the hydraulic fluid from the nitrogen.
- Active manifold. This manifold is located on the starboard side of the heave system. It contains the servo valves and boost valves and other functions needed for active heave control.
- General Emergency stop buttons are provided on the HPU frame and winch local control cabinets. These switch off all electrical motors and both HPU motors. This stop will NOT affect the main valve of the passive heave compensator.
- A "passive heave" emergency stop button is located near the moving main sheave. This switch will close the main valve of the heave compensator.

WARNING



Especially when connected to the seabed the passive E-stop should not be used as major damage could result if the moving ship gets rigidly locked to the seafloor when the main valve is closed.

4.9 MOTION REFERENCE UNIT (MRU)

Near the port base of the main cylinder the MRU sensor is fitted. This sensor detects all ships movements (pitch, roll, yaw, and heave). The signals are send directly to the PLC and processed in order to make a difference between the various deployment modes. The 300 mT winch can be utilized on port and starboard, as well as to the moonpool in the centre of the ship. The way of deployment has to be selected on the bridge using the SCADA screen.

4.10 BRIDGE CONTROL

On the bridge the following controls can be found:

- Starting the DC bus from the SCADA EPU screen (see Figure 4-3 until Figure 4-5). The ships mains need to be switched on in both port and starboard switchboards near the heave compensation system in the hold.
- Starting the HPU system from the SCADA HPU screen.
- The deep water winch system is controlled by a joystick located on the desk.
- The heave system is controlled by push buttons on the desk, using SCADA to monitor the heave system parameters.
- Enable keys witch on the desk for the WAB (Walk Around Box) for deck control of the 300 mT winch system.
- A general Emergency stop which switches off all electrical motors and both HPU motors. This stop will NOT affect the main valve of the passive heave compensator.
- A "passive heave" emergency stop which will close the main valve of the heave compensator AND it will stop all electric motors.

WARNING



Especially when connected to the seabed the passive heave E-stop should not be used as major damage could result if the moving ship gets rigidly locked to the seafloor when the main valve is closed.



Figure 4-3: OPERATIONS > POWER > EPU

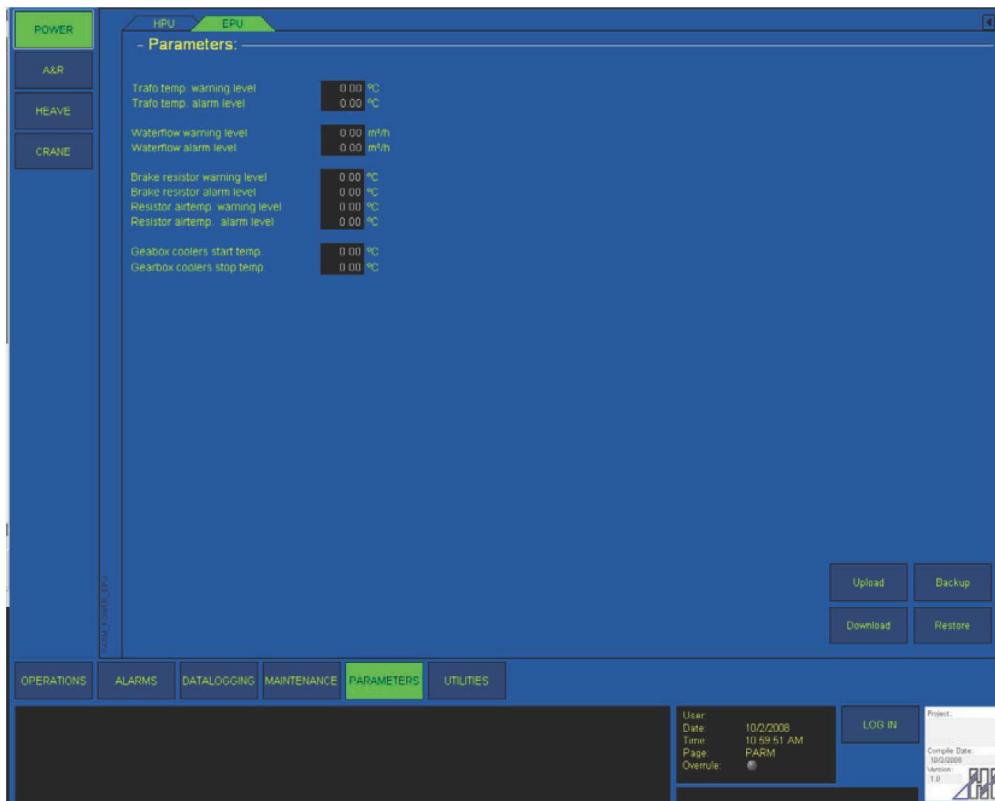


Figure 4-4: PARAMETERS > POWER > EPU

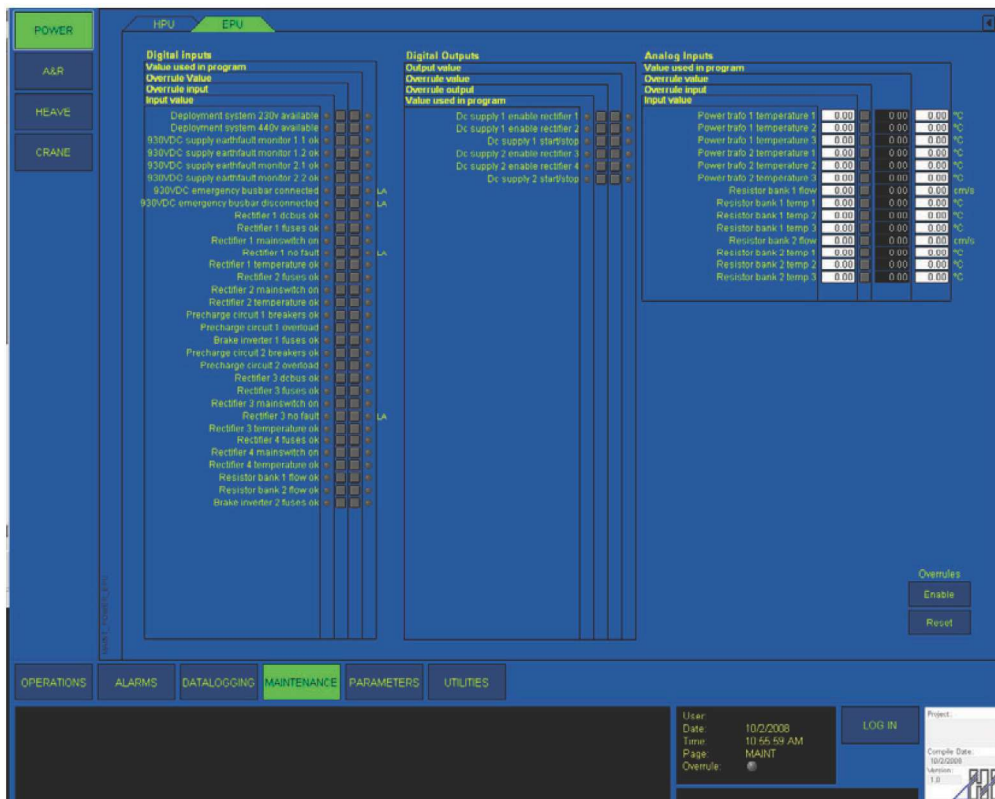


Figure 4-5: MAINTENANCE > POWER > EPU



Figure 4-6: OPERATIONS > POWER > EPU

4.11 DESCRIPTION OF ELECTRICAL CABINETS AND LOCATIONS

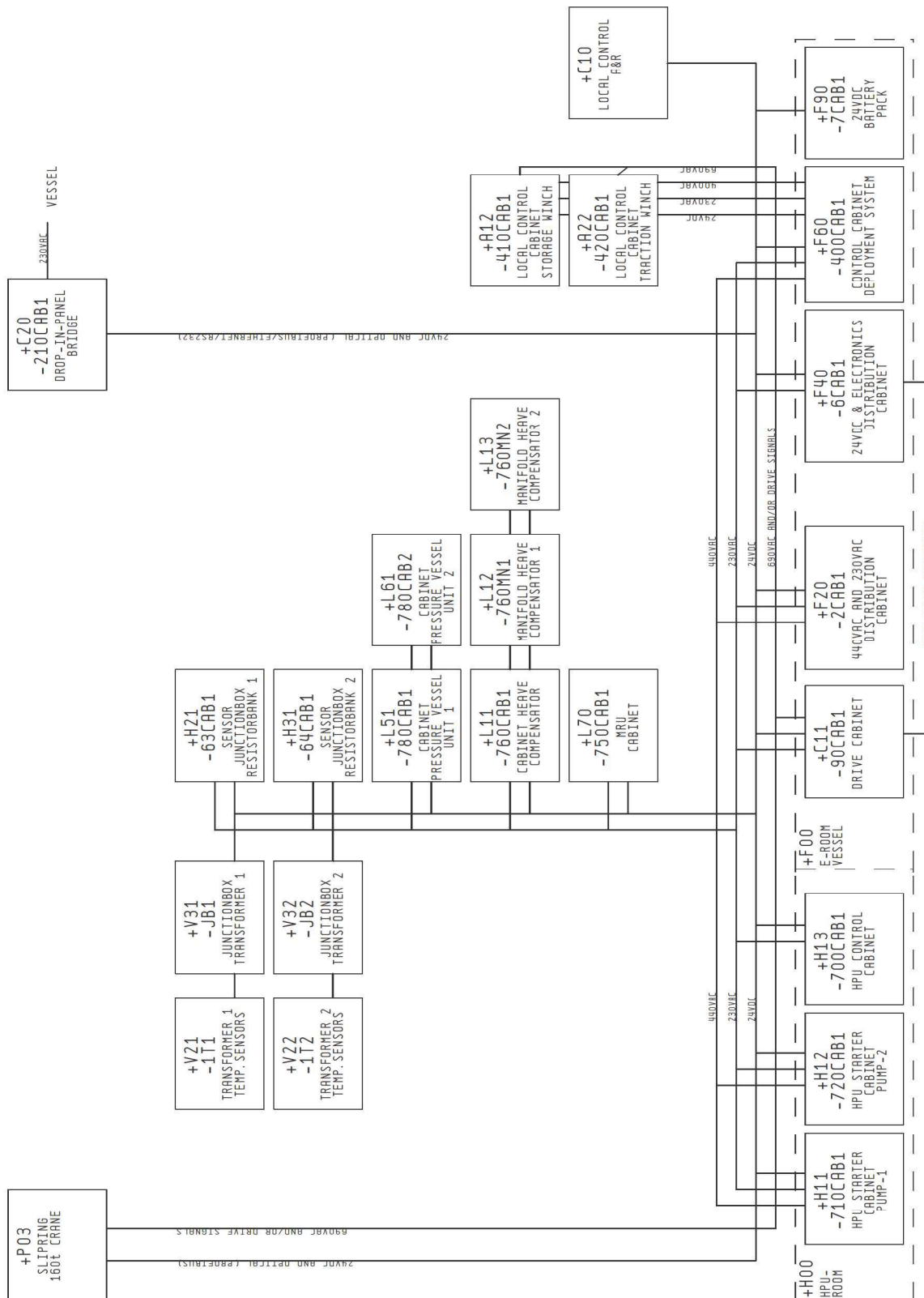
This section describes the cabinets used for the:

- 300 mT DWLS
- HPU

The cabinets for the "Passive and Active heave system" and the Bridge Control are described in the 300 mT DWLS section.

See Appendix Q: "Location designation overview" for the location designation overview.

4.11.2 300 mT DWLS cabinets



See Figure 4-9 on page 81. The following components will be described:

E-cabinets inside starboard 440 Vac ships switchboard (+F20-F40-F60 and C11)

Storage winch (+A10)

Traction winch (+A20)

MRU cabinet (+L70)

WAB Walk Around Box (+C10)

Bridge control station (+C20)

Battery pack (+F90)

4.11.2.1 E-cabinets

The POCA (+F20), the winch ELCA (+F40), the heave ELCA (+F60), and drive cabinet (+C11) are located in the starboard 440 Vac ships switchboard room.

4.11.2.2 Storage winch (+A10)

The storage winch can be operated with local control cabinet (+A12). From this cabinet it is possible to control the storage winch. More info see section on page 4-65. During special procedures like to put storage wire again in CT mode or during reeving the local control cabinet could be used.

4.11.2.3 Traction Winch (+A20)

The traction winch can be operated with local control cabinet (+A22). From this cabinet it is possible to control the traction winch. More info see section on page 4-65. During special procedures like to put storage wire again in CT mode or restore new wire the local control cabinet could be used.

4.11.2.4 MRU cabinet (+L70)

This is an interface box for the MRU (motion reference unit). This sensor senses all ships movements at high accuracy. The box is equipped with a small PLC unit which is used to feed the data of the MRU into the heave PLC via the profibus network.

4.11.2.5 WAB Walk Around Box (+C10)

- This is a box that enables control of the DWLS when the swivel is near the deck, or during reeving in or out of the wire through the deck beam. The box has an emergency stop and two buttons to command the DWLS up or down.

WARNING



Avoid serious damage:

During creeping speed attention has to be taken. When passing the "high" position visual observation is necessary. Keep in mind the impact of the heave compensator. Due to the fact there isn't a highest position sensor located at the deckbeam, the hook can be pulled against the deck beam.

Suggestion: De-activate the heave compensation after passing "high" position.

The speed ramps up to max 15 % speed in both directions. The emergency stop is always incorporated in the E-stop circuit, so care has to be taken not to actuate this by accident. In order to operate with the WAB it is necessary to switch the enable keyswitch "WAB enable" on the bridge desk. This is done to make sure no accidental movement of the 300 mT winch with this box will happen.

4.11.2.6 Bridge control station (+C20)

On the bridge remote IO station is present that transfers the operator switches and joystick signal to the winch and heave PLC. For monitoring the process a SCADA screen is fitted. For operation of the heave system the SCADA screen is always necessary. See Section 5: "Operation" on page 85 for more information on operating the DWLS.

4.11.2.7 Battery pack (+F90)

The battery pack serves as a back up (UPS) supply for critical 24 VDC control systems. The battery is maintained by a fully automatic battery charger inside POCA F20. On the left side of the box a switch is added to enable the disconnection of the battery when it is needed to shut down all ships supplies. Failing to switch off the battery will lead to exhausting the battery, which will cause premature failure of the battery.

WARNING

The system will function as normal with a bad (or switched off!) battery, but at a power failure all control systems will instantly be lost, and it will take minutes before the control system is back on line again. For this reason it is necessary to check the condition of the battery at regular intervals, and make sure the switch is on. The switch is on when the lever has moved down in its groove.

4.11.3 HPU (Hydraulic Power Unit) CABINETS

The HPU cabinets are located at the HPU-plateau (+H00) in the hold. They are located in the same room like the HPU, heave compensator and traction and storage winch. The following cabinets will be described:

- HPU starter cabinets (+H11) and (+H12)
- HPU control cabinet (+H13)

4.11.3.1 HPU starter cabinets +H11, +H12

The complete power unit is controlled and started from the 3 cabinets mounted on the plateau. All the motors are started from the 2 power cabinets +H11 and +H12. Most pumps are equipped with hour counters. Note that the main pumps require greasing every 4200 hours. The cooling pumps require greasing every 10.000 hours. More information can be found in the ABB section of the supplier documents.

All I/O generated inside these cabinet is connected to local remote i/o units in +H13. This includes supplying the actual start and stop commands for the pumps. Refer to the software manual for more information about these signals

During normal operation, cabinet +H11 is used to start the main pump of pumpset 1. Cabinet +H12 is used for pumpset 2. Inside the cabinets the star-delta switchgear is fitted for both Main HPU motors. Starting and stopping can be done local from these cabinets, and also from remote using the SCADA screen on the bridge. A local start or stop will overrule the bridge. The status on the bridge will show which pumps are operational. HPU Control cabinet +H13

Most sensors and valves that supervise and control the HPU's are connected to this cabinet. In this cabinet the remote IO station is situated which transfers all signals back and forth to mainly the heavy PLC. A light is available on the cabinet doors which indicates that the 230V control power is available. This light gives no information about the 24V required for the remote i/o station. The 24 VDC supply that feeds the remote IO station and other critical parts is obtained from cabinet +F40 which is located inside the starboard 440 Vac ship's switch room.

During an emergency stop, several contactors inside these cabinets must open. This is checked by the emergency stop relays in cabinet +H13. If this has not happened, it is not possible to reset the emergency stop situation.

WARNING



Make sure to switch the power in the cabinet off before doing maintenance in the cabinet.

WARNING



Be careful before opening any cabinet! After switching the power off it will take several minutes before the voltage on the copper rails is safe!

WARNING



Apart from waiting several minutes before opening the cabinet after switching, check the voltmeters mounted on the first cabinet to verify if the voltage is zero volts.

5 OPERATION

5.1 INTRODUCTION

This section describes the control system and operation of the 300t Deep Water Lifting System. The purpose of the DWLS is to set down / lift off equipment from the seabed. The system comprises a storage winch and a traction winch. The storage winch is used for storing the wire rope, but it cannot handle the full load for which the system is designed. This load is taken by the traction winch which comprises two drums which are not mechanically coupled. These can hold the full load, but only when the storage winch is in "Constant Tension" (CT) mode pulling with a fixed setpoint to build up enough friction in the traction winch.

5.1.1 Control locations

For maintenance and initialization of the system, local operator panels are provided near the winches. All controls are carried out in hardware (pushbuttons, pilot lights and a joystick).

For normal operation there is a control station provided on the bridge (pushbuttons, pilot lights, joystick), but also including a SCADA system.

5.1.2 Main control console

The main control console contains two identical control panels and SCADA stations. The control panels (see Figure 5-10) are described in this section.

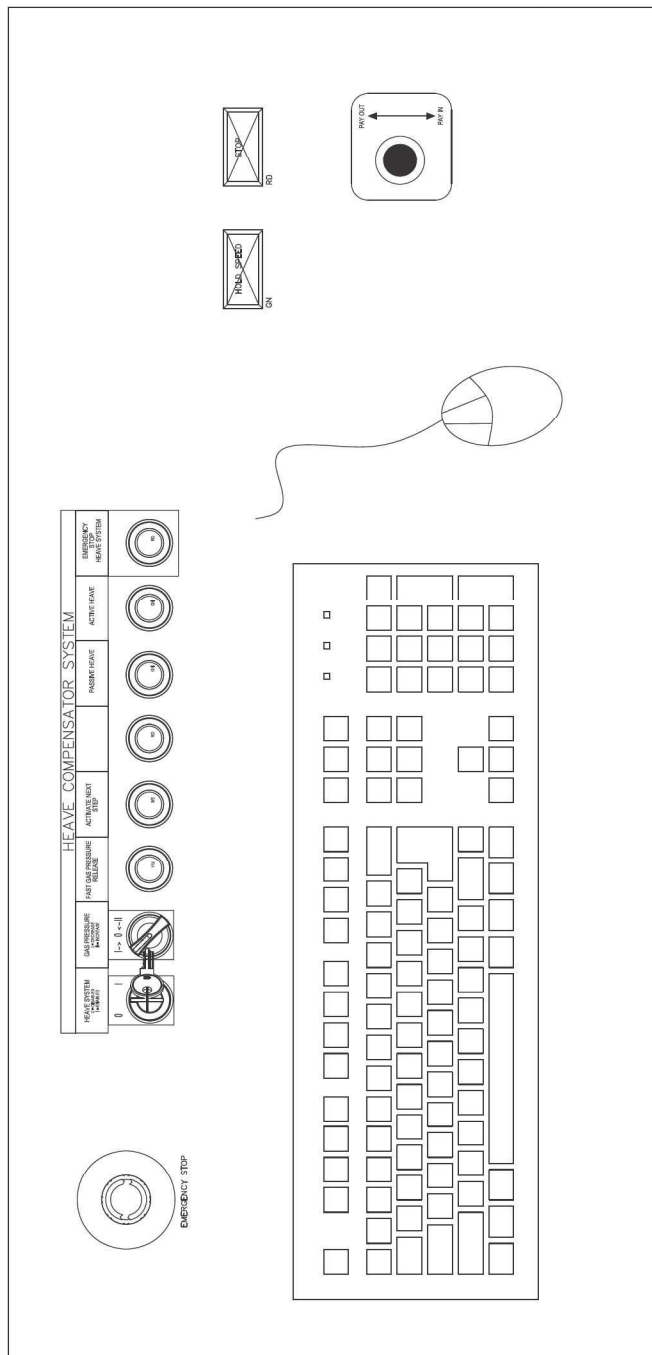


Figure 5-10: Main control desk

The following controls are located on the control desk:

1. DIMMER for panel lights.
2. The BUZZER emits audible signals, see Section : "Buzzer Handling" on page 97 for more information.
3. When the LAMP TEST button is pushed all indicators (lamps / buzzer) on the desk containing the button are activated until the button is released.
4. The RESET EMERGENCY STOP button sends a reset signal to the emergency stop relay when pushed. This button also resets ISPS failures. If the emergency stop is active the indicator in the button is lit steady. If an ISPS alarm is active the indicator blinks.
5. The RELEASE CONTROL button releases all controls which the corresponding SCADA station would have. On the SCADA system control can be taken for several subsystems. Normally, control is also released again via SCADA, but in the event the SCADA system fails while holding control it would not be able to release control again. The indicator in the button is lit when the SCADA system has taken control of at least one system.
6. The ACKNOWLEDGE FAILURES button silences the buzzer. The indicator in the button is lit when the buzzer is sounded.
7. The RESET FAILURES button removes all alarms that are no longer active but are not reset yet. Movements are held off until the alarm is removed. The indication in the button is lit when an alarm that was present is no longer active but was not reset yet. This to indicate that an alarm can be reset.
8. The EMERGENCY STOP button is hardwired directly to the emergency stop relay. The control system merely displays the status of the button.
9. Key switch HEAVE SYSTEM to enable or disable the heave compensation system.
10. Switch GAS PRESSURE to increase or decrease the gas pressure in the pressure vessels. By varying the pressure of the gas the system can be adjusted to different static loads. See Section 5.5.7: "Charge/drain cycles" on page 132 for more information.
11. Push button FAST GAS PRESSURE RELEASE to activate the fast gas release function used when lifting loads from the seabed. See Section 5.5.8: "Fast Gas Release" on page 138 for more information.
12. With the ACTIVATE NEXT STEP button it is possible to perform a semi-automatic heave compensator operation sequence, step by step. A number of different sequences are programmed in the control system. Depending on the type of operation and the operating conditions the operator can select a predefined sequence in which a number of actions are performed automatically by the control system. A detailed stepwise explanation of each automatic sequence is included in Appendix O: "Heave compensator - Automatic sequences".
13. A "normal" emergency does not include the HPU and heave compensator. With the EMERGENCY STOP HEAVE SYSTEM the main valve of the heave compensator is deactivated.
14. Pressing the HOLD SPEED button once while operating the joystick will hold the current pay in / pay out speed. When the joystick is released, the current speed will be retained until the joystick is operated again.
15. Press the STOP button to stop the movement of the winch system. The light in the button is lit when the corresponding state is active.
16. The joystick is used to manually control movement direction and speed of the device(s) selected with the movement selection buttons. When released the joystick veers back to

the middle (neutral) position and the movement controlled with the joystick consequently stops. The signal from the joystick is curved with a quadratic function to provide proper control at low speeds.

5.1.3 Explanation of operating modes

Constant Tension (CT) mode

Constant Tension (CT) mode means that the control system constantly regulates the motor torque to a fixed setpoint given by the operator. The actual tension is measured by the load cells. These load cell signals are used as feedback for the CT regulation. If the tension changes the control system will adjust the motor speed in order to regulate the load back to the setpoint.

As a really fixed tension setting is hard to realize, the control system will allow the tension to vary within a window of 5t below and above the setpoint (so the acceptable limits are between 10 and 20t). When the measured line pull exceeds this window the brakes will be applied and the tension will have to be controlled back to the setpoint in speed mode.

Speed mode

In speed mode the motor torque increases or decreases depending on the position of the joystick. The joysticks are proportional to achieve accurate control at low speeds; a relatively large joystick deflection is required to enter the high speed regions. In a standstill situation the brakes are applied, in movement the motor torque will be higher (pay in) or lower (pay out) than the load acting on the wire rope.

Service mode

In service mode all safeties can be overruled and the storage winch can be operated separately from the traction winch. Also, the two drums of the traction winch can be operated separately. Service mode is used for maintenance, reeving and problem solving.

WARNING



Although the A&R system is protected against overload by means of a load cell, there is a possibility to override the overload protection. The operator must make sure that this override is used to correct a problem only if absolutely necessary.

NOTE

Hoisting the load will reduce the force on the A&R wire rope because the weight of the cable decreases, while lowering will increase the load. An overload could occur if the operator tries to lift more than the specified weight. In order to prevent this, the weight of the loads to be lifted have to be known. It should then be checked if the required depth can be reached with the current load on the A&R wire rope (the weight of the cable is significant).

5.1.4 System modes

In normal mode the traction winch operates in speed mode, determining the pay-in/pay-out speed of the wire. The storage winch keeps constant tension on the wire between the storage and the traction winch to keep the wire from slipping on the traction winch. In this mode the two drums on the traction winch are always operated simultaneously.

In service mode both the winches can be operated manually from their own local control stations in speed mode. This provides a means of operating the winches for purposes of maintenance and initialization (e.g.: reeving of the wire). In this mode the drums of the traction winch can be operated independently, although this is not advisable due to the high friction and wear of the wire.

5.2 SCADA

5.2.1 General description

The SCADA system is used for visualization of the operations. It may also be used to enter parameters used for the deep water deployment process and to enter commands for manual operation of the (sub)system(s). Furthermore, it provides logging and trending capability to store process values over a period of time. SCADA is started automatically when the respective PC is started and can only be shut down (utilities menu) by users with administrator access level.

SCADA includes operational and maintenance pages for all subsystems as well as various alarm and general pages.

It comprises of operational and maintenance pages for all the sub-systems. Furthermore, pages show the status of the control system. The general requirements for the SCADA system are described here, the various subsystem requirements contain also their own SCADA requirements, these are described on their own document.

5.2.2 User levels

The following operating levels can be distinguished, each with its own permissions. The user level is determined by the password, and by the location. Each user level has its own unique password. Depending on the location a certain user is logged in:

- No user: Can view a selection of the pages. no actions can be performed.
- Operator: Can view all pages and give manual commands.
- Engineer: All operator actions + using service mode, overruling inputs, calibrating length measurement systems, entering pipelay parameters, trending process values.
- Administrator: All operator actions + shutting down SCADA, managing users

5.2.3 Screen structure

The tree diagram in Figure 5-11 represents the complete menu structure of the SCADA system.

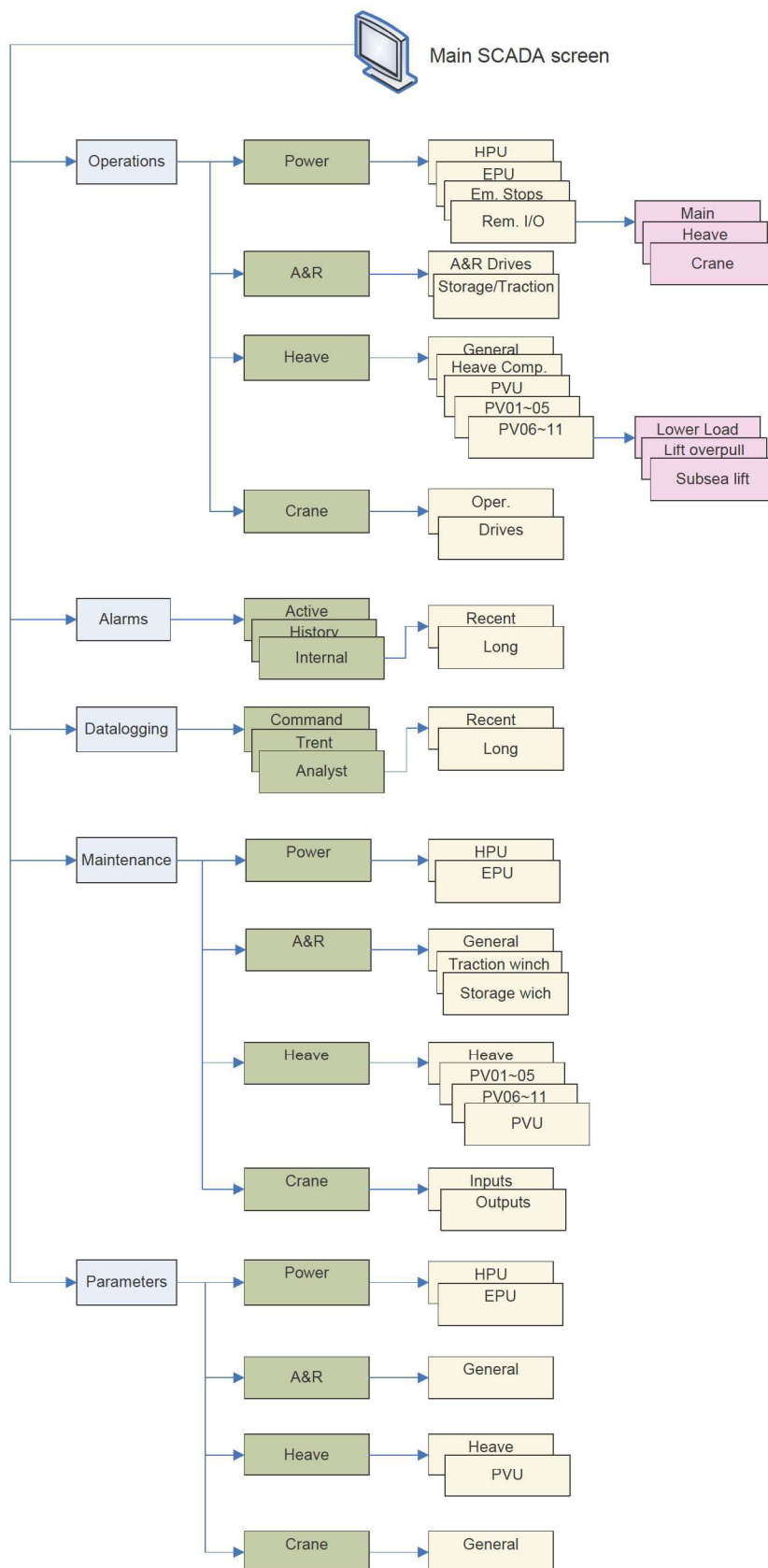


Figure 5-11: SCADA menu structure

Figure 5-12 shows the lower section of a random SCADA screen. In this case the OPERATIONS window is active. The buttons at the left (A) allow switching between the various windows of the SCADA system.

NOTE *The UTILITIES button is only visible if you are logged in as administrator.*



Figure 5-12: Lower screen section

Alarms and messages are shown in the bottom section (B) of the screen. For more information of the Alarm and message handling refer to Section 5.2.7: "ALARMS menu".

The log in/out section (C) shows information on who is logged in (user).

5.2.4 Control location

To hand over control to and from the control cabin, buttons on the SCADA screen are provided.

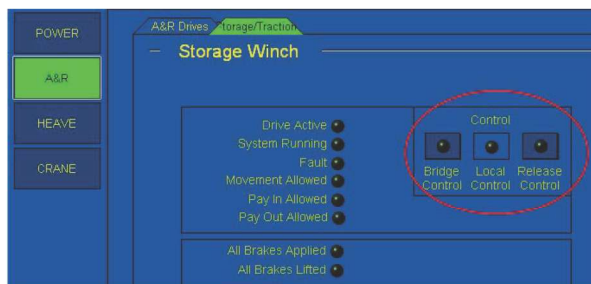


Figure 5-13: Control location buttons

On the local panel, buttons are used for control handover. Every handover movement must be affirmed by the location which has control.

A control request has to be answered by a control release. When a release is not given, control remains at the current location. A time-out message is generated.

5.2.5 Handover procedure

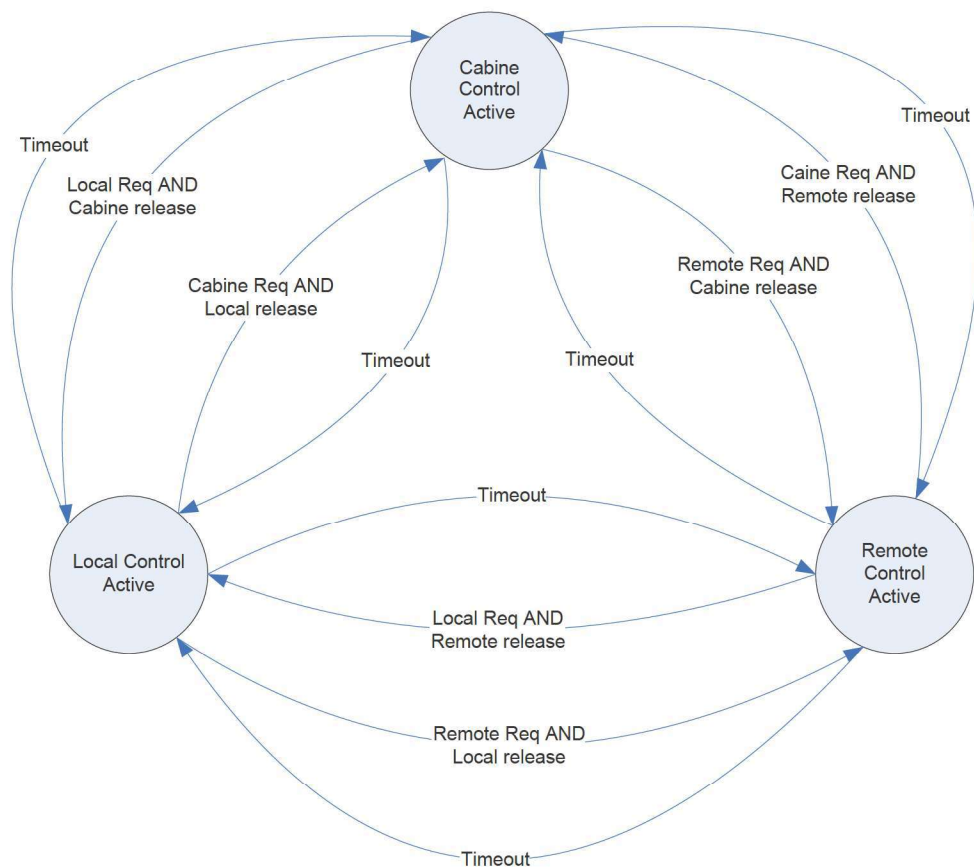


Figure 5-14: Control handover

- Handover of the control is only allowed when the system is not moving.
- To handover the control the operator which wants to have to control has to push corresponding button (local control).
- The location which has the control has to release the control by pressing the button on that location (release control).
- On both panels the button that indicates which location is in control is lit.
- When handing over the control the button to which the control is being handed over flashes.
- When a control request is not granted in 10 seconds the request is canceled.
- Default control location (PLC first scan) is the control desk.

5.2.6 OPERATIONS menu

When the OPERATIONS button is activated, a page as in Figure 5-15 for example will show. In this case the HPU tab within the POWER pages is shown.

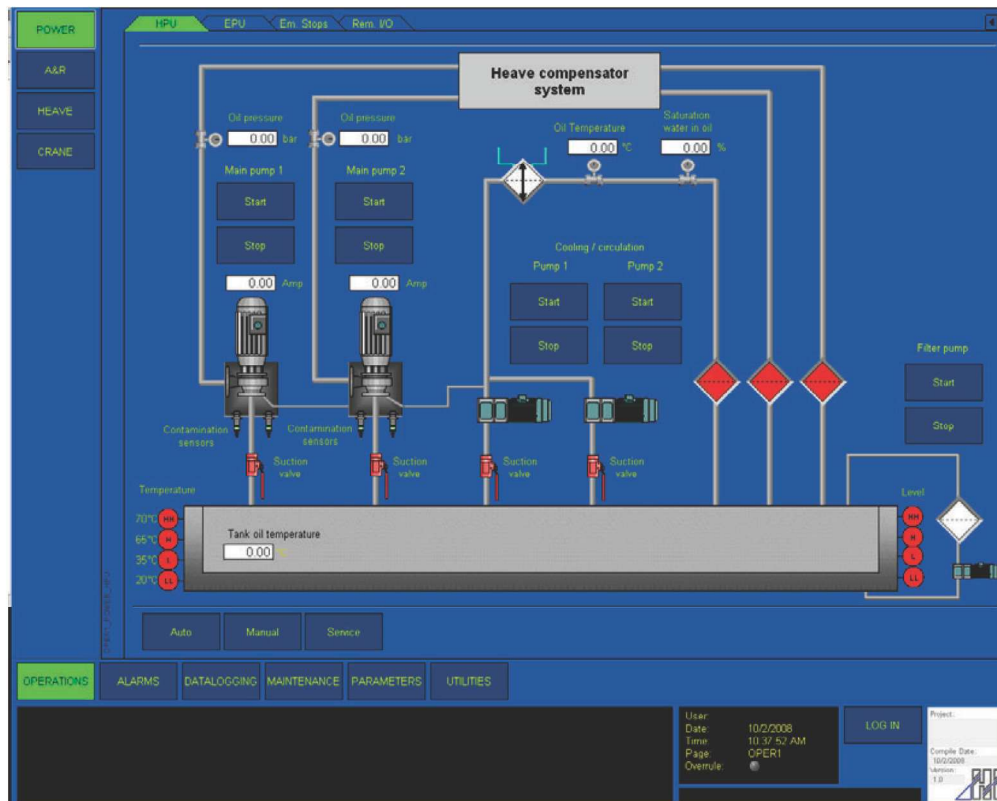


Figure 5-15: OPERATIONS > POWER > HPU

The various operations screens are discussed separately.

5.2.7 ALARMS menu

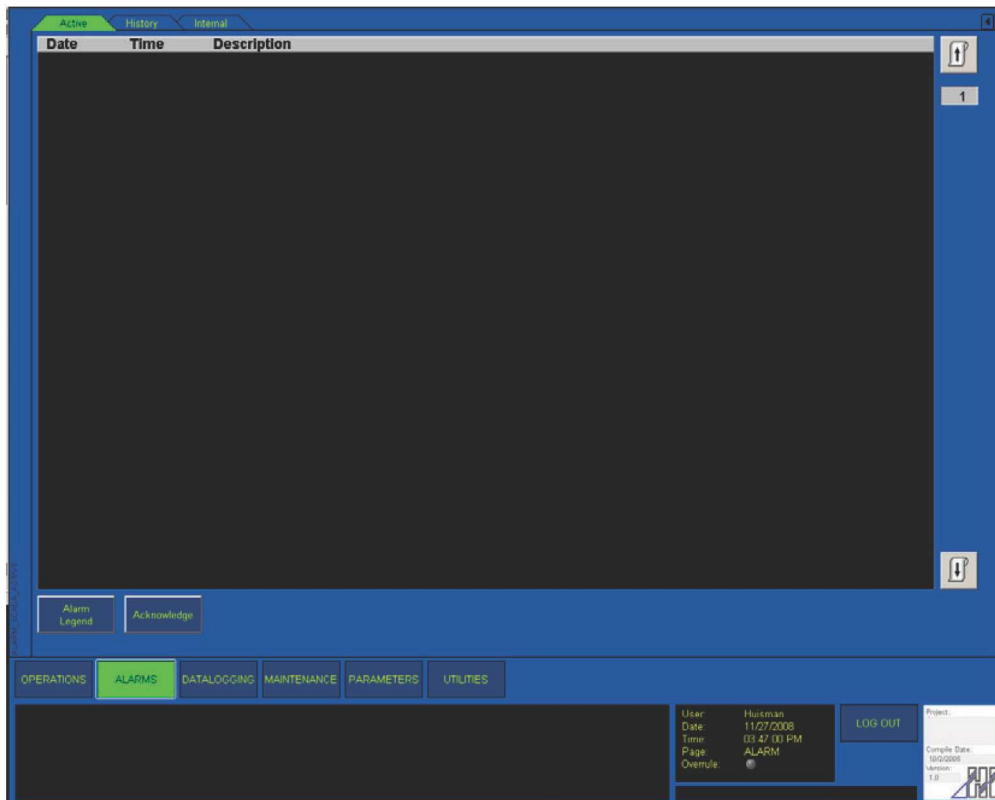


Figure 5-16: ALARMS menu

The operator is informed about system events through messages appearing at the bottom of the SCADA page, see Figure 5-16.

A clear distinction must be made between the following definitions:

Messages

A message is any event that is notified to the operator. This can be an alarm, a warning or an invalid command.

Alarms

Alarms indicate a situation which is/can be hazardous to man or installation (e.g. sensor out of range, overload etc.).

Warnings

Warnings notify the operator that a hazardous situation is to be expected unless precautions are taken (e.g. high load).

Invalid commands

Messages to notify the operator that an interlock prevents an action.

Three different states are defined for an event:

Active

An event is active if the event conditions are true.

Set

An event is set (stored) when it is active. It can only be reset when it is not active and acknowledged.

Acknowledged

An event is acknowledged when it is set and acknowledged.

The operator has 2 buttons for event handling:

Acknowledge button

Serves to indicate to the control system that the operator is aware of the event; silences the acoustic alarm (buzzer) and permits to continue operation.

Reset button

Resets all inactive and acknowledged events.

Note that invalid command messages cannot be acknowledged, they will disappear automatically after two seconds.

When an event is active it is automatically stored by the event handling function. An operator acknowledges the event. When an event has been acknowledged and is not active it can be reset by the operator.

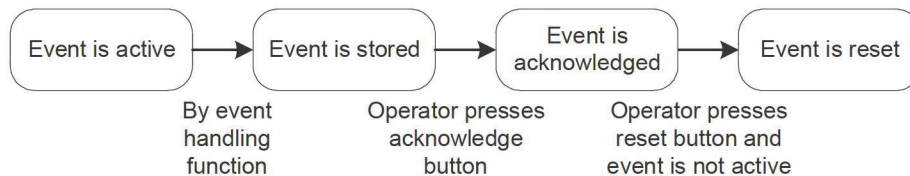


Figure 5-17: Message handling event flow

The event flow shown in Figure 5-17 is used in case the event is an alarm or a warning. In case of invalid commands, acknowledgement and reset is done automatically i.e. after a certain time.

Buzzer Handling

The buzzer is sounded on any new event. The buzzer signals are different for each event type:

- Alarm : Continuous until silenced by operator
- Warning : Intermittent until silenced by operator
- Invalid command : 3 intermittent beeps
- Load cell overrule : 3 intermittent beeps every 5 minutes

For alarms and warnings the buzzer can be silenced using the *Acknowledge* button.

The most recent, active alarms are represented in the bottom part of the SCADA screen. A more extended list of unacknowledged alarms can be viewed on the alarm page. After the alarm has been acknowledged and reset, it is moved to the alarm history list, where it is kept on record in two stages. The *'Recent history'* and *'Long history'* alarm pages both keep record of past alarms. This record is kept for up to two months in the *'Long history'* alarm page. The alarm history can be exported in a format which can be read by Microsoft Excel. An option to filter the alarms is also available.

Apart from alarms there are also warnings and notification messages. Alarms and other messages are generated in the following situations:

- Detectable sensor failures (detection possible for 4-20mA, SSI and Namur sensors)
- Detected sensor discrepancies (e.g. lock and unlock sensor seen at the same time)
- Detected actuation inconsistencies (e.g. fan is commanded to run but not running)
- Detectable circuit breaker failures
- Invalid commands (command that is prevented by an interlock)

The operator has 2 buttons for alarm handling:

- | | |
|---------------------|--|
| Acknowledge button: | Silences the buzzer and acknowledges all active alarms to indicate that the operator is aware of the alarms. |
| Reset button: | Resets all inactive and acknowledged alarms to resume operation. |

Emergency Stop

The emergency stop is a hardware stop. Power is removed from all actuators, causing a crash stop on each system. An emergency stop is activated by pressing one of the emergency stop buttons. Before power is restored all emergency stops have to be unlocked (turn to let them spring back to the neutral position), and the emergency stop must be reset.

The emergency stop is also activated in case of a failing PLC, by means of a watchdog interface. The watchdog generates a pulse to a relay. When the pulse train stops this is interpreted as a PLC error and the emergency stop will be activated.

In order to reset the emergency stop not only the emergency stop circuit, but also the reset circuit must be restored. In this circuit all the starter relays are integrated to ensure that no relay is activated by the PLC, which would cause an unexpected movement when the emergency stop is reset. When the emergency stop is reset each movement must be re-initiated, the system will not start any movement automatically.

The status of all emergency stop buttons and relays is visualized in SCADA (see Figure 5-18).



Figure 5-18: OPERATIONS > POWER > EMERGENCY STOPS

5.2.8 DATALOGGING menu

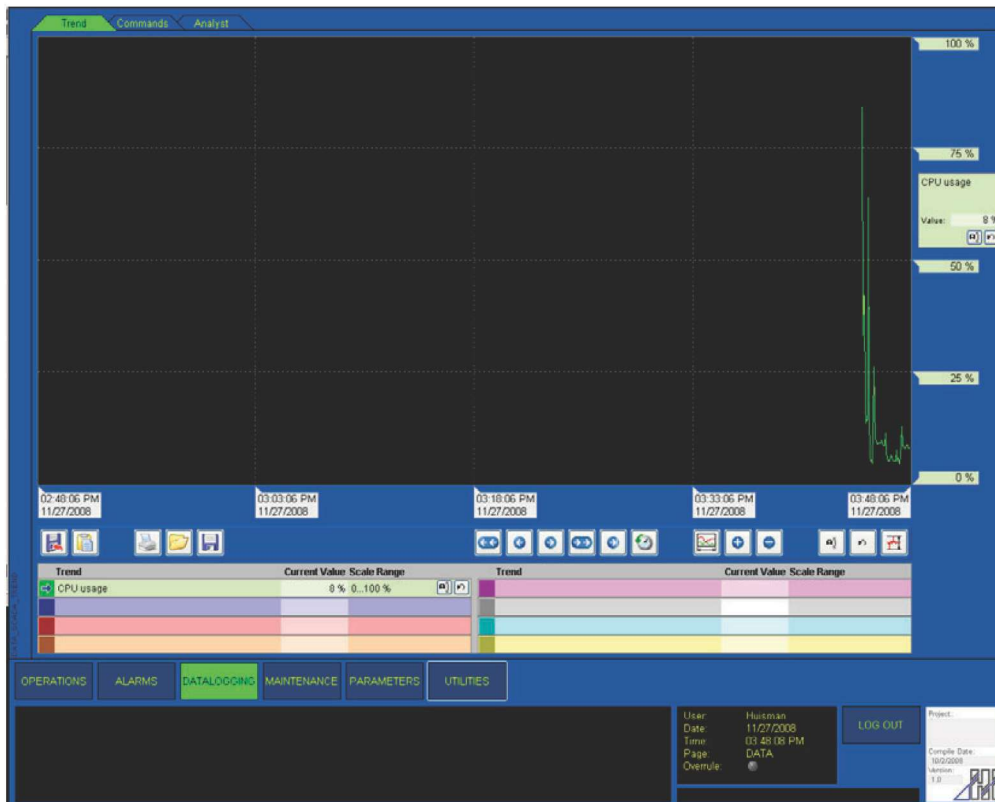


Figure 5-19: DATALOGGING menu

Trending

Trending is the recording of values. This can be done periodically or triggered by an event. The SCADA system trends data periodically (once per 250ms). Per system a list is given with the values (variables) to be recorded. These can be selected by the operator. Trend files can be exported in a format which can be read by Microsoft Excel.

The trends to be displayed are selected by clicking in one of the squares below the main part of the trending page. This calls forth a popup in which the trends can be selected, see Figure 5-19.

Logging

Logging is the recording of events. The following events are logged:

- System mode (automatic, manual, service, etc.)
- User logon/logoff
- All SCADA button actuations (overrules, movement commands, etc.)
- All desk button actuations
- All digital inputs and outputs
- Operator notes (operators can enter notes in SCADA; these are stored with a time stamp).

Log files can be exported in a format which can be read by Microsoft Excel.

5.2.9 MAINTENANCE menu

The maintenance pages are used to overrule inputs and outputs during maintenance or commissioning. From an operational point of view overruling inputs can be useful to overcome problems caused by a defective sensor or by operations deviating from the way the system was intended/designed.

WARNING

Overruling outputs can be very dangerous and may therefore only be done by persons with adequate permissions having a thorough knowledge of the system!

An input (or output) is selected for overruling and the desired value is set (true/false or value). A reset button on the maintenance page resets all active overrules.

This means that an input/output apart from the 'program' value which is used in the program, also has an 'overrule active' and an 'overrule value'. Each of the 3 values is stored in a separate data block. For analog inputs/outputs also a data-block containing the scaled value of the input/output is defined.

5.2.10 PARAMETERS (settings) menu

The parameters pages for each subsystem are accessible through the maintenance tab and permit to enter/change parameters as well to calibrate encoders (in general this is only required after replacement of an encoder or in case of a PLC breakdown).

The system has several types of parameters: winch parameters, heave compensator settings and system settings. The winches and heave compensator parameters screen is accessible through a button on the operational pages, the other parameters can only be accessed from the maintenance pages, by selecting the *Parameters* button. All parameter sets are stored on the SCADA PC in the form of an Excel file. The SCADA system has a provision to download these parameters to the PLC. This means that after for instance replacing a CPU all settings can be downloaded and operation can be resumed very quickly without having to recalibrate all encoders etc. It also means that a pipelay parameter file can be sent from the main office to the vessel and downloaded into the PLC.

5.2.11 UTILITIES menu

The utilities menu permits to add or change users and passwords, to shut down the system and further provides some auxiliary functionality. The utilities menu is accessible from all pages through a button at the bottom of the screen.

5.3 HYDRAULIC POWER UNIT

5.3.1 Introduction

This section presents a global description of the functions of the Hydraulic Power Unit. The HPU is designed to provide hydraulic pressure for the Heave Compensation System.

The main components of the power unit are:

- 2 electrical main pumps
- 2 electrical circulation pumps
- 1 electrical filter pump
- Various valves
- Hydraulic oil tank

In the power unit two electrical motors are mounted for the hydraulic pumps to provide the main power/pressure, and the two cooling pumps are mounted to circulate the oil through a oil/water heat-exchanger. One of these pumps is intended to be a back-up for the other pump in case of failure. The filter pump circulates the oil through a filter to catch contaminations in the oil.

Oil level and temperature are monitored, as well as the level of saturation/contamination of the filters. Furthermore, oil pressures and valve positions are monitored at various points in the system. Monitoring and protection of these systems is performed by a PLC.

System Modes

The HPU can be operated in automatic, manual or service mode.

Automatic Mode

The system starts/stops the pumps according to a pre-programmed sequence. This is the recommended method of operating the HPU in normal use.

Manual Mode

Pumps can be started/stopped manually and in any order, but safety conditions are still in force.

Service mode

All safety conditions are disabled (save the emergency stop) to provide ways vice engineers to test and commission the HPU.

Control Locations

Operating the HPU can be done locally on the power cabinet, or on the SCADA system. Control location selection will be done on the SCADA system (see Figure 5-20).

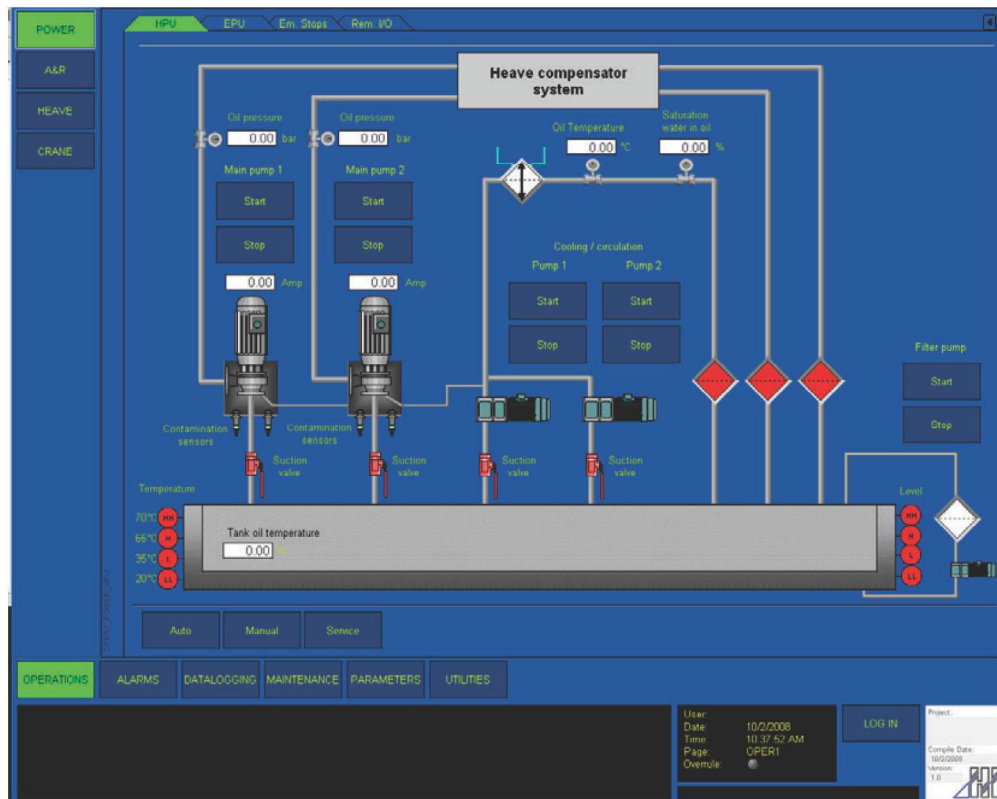


Figure 5-20: OPERATIONS > POWER > HPU

5.3.2 General system

Operational

The HPU system is operational if all of the following conditions are met:

- Remote IO unit ok.
- No emergency stop

Running of the HPU is only allowed if the system is operational. The HPU is considered running if at least one of the main pumps is running and there is no system pressure failure for that pump.

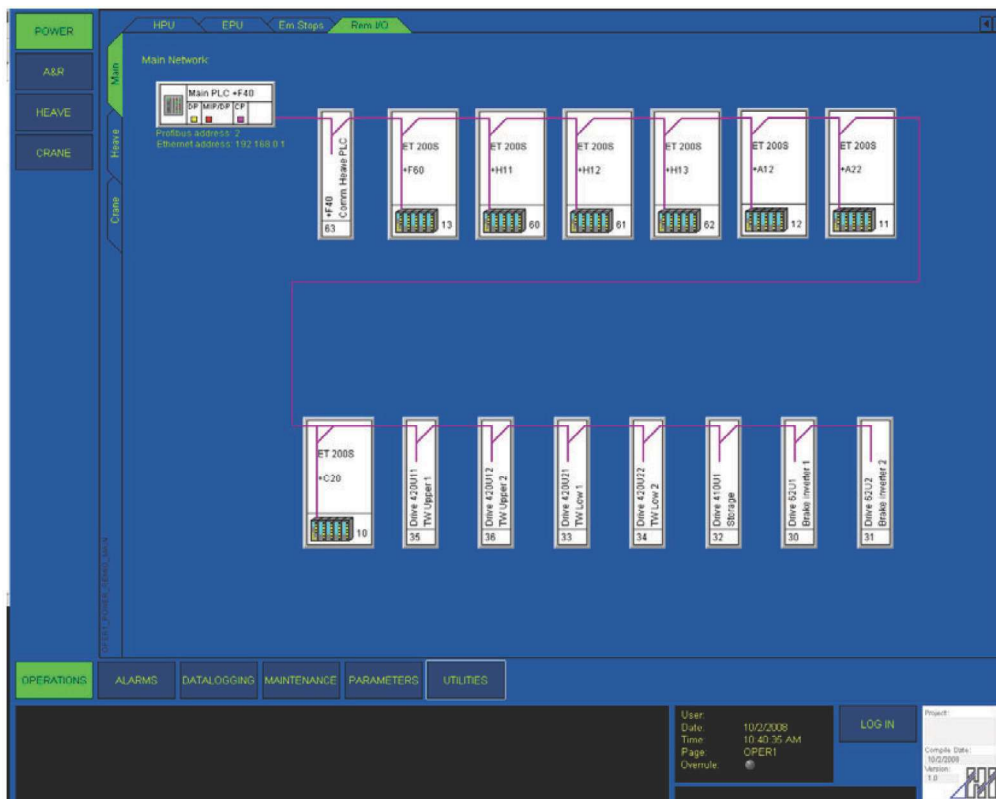


Figure 5-21: OPERATIONS > POWER REMOTE I/O > MAIN

Operating modes

The HPU can be in one of the following modes:

Automatic mode

All selected pumps are started automatically and in sequence when pressing the “start HPU” button on the SCADA system. All pumps are stopped by pressing the “stop HPU” button. Starting and stopping is according to the sequences shown in Figure 5-22. A pump which is not selected (via SCADA) will be ignored in the automatic sequence.

Manual mode

Each pump must be started and stopped individually.

Service mode

Same as manual mode except no safety conditions are in force (except the emergency stop).

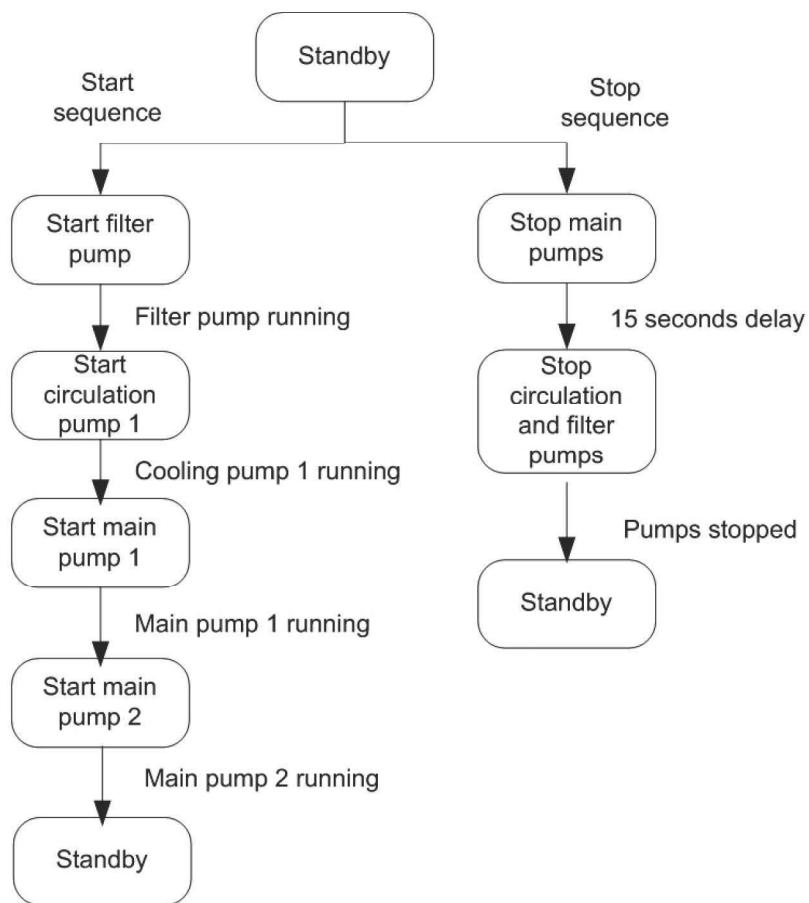


Figure 5-22: Start/stop sequences

WARNING



Filterpump is not stopped in the stop sequence !

Control location / handover

There is no handshaking protocol to switch between control locations; in manual mode both locations operate the HPU in parallel. Selection of the operating mode (and indirectly control location) is done on the SCADA system.

- Each pump can be operated locally if the system is in manual mode.
- Each pump can be operated remotely from the SCADA if the system is in manual mode.
- The HPU can only be operated in automatic/service mode from the SCADA only.

Alarm handling

- An alarm is generated for each detectable sensor failure (possible for 4-20mA, SSI, and Namur sensors).

- An alarm is generated for each detected sensor discrepancy (lock & unlock sensor seen at same time etc.)
- An alarm is generated for each detected actuation inconsistency (fan is commanded to run but not running and vice versa, etc.)

Invalid commands are generated for each interlock which prevents an action unless this interlock is an alarm or warning which already generates a message.

Visualization

The HPU will have separate SCADA operational and maintenance pages. The SCADA maintenance page is shown in Figure 5-23. Figure 5-24 shows the parameters screen for the HPU.

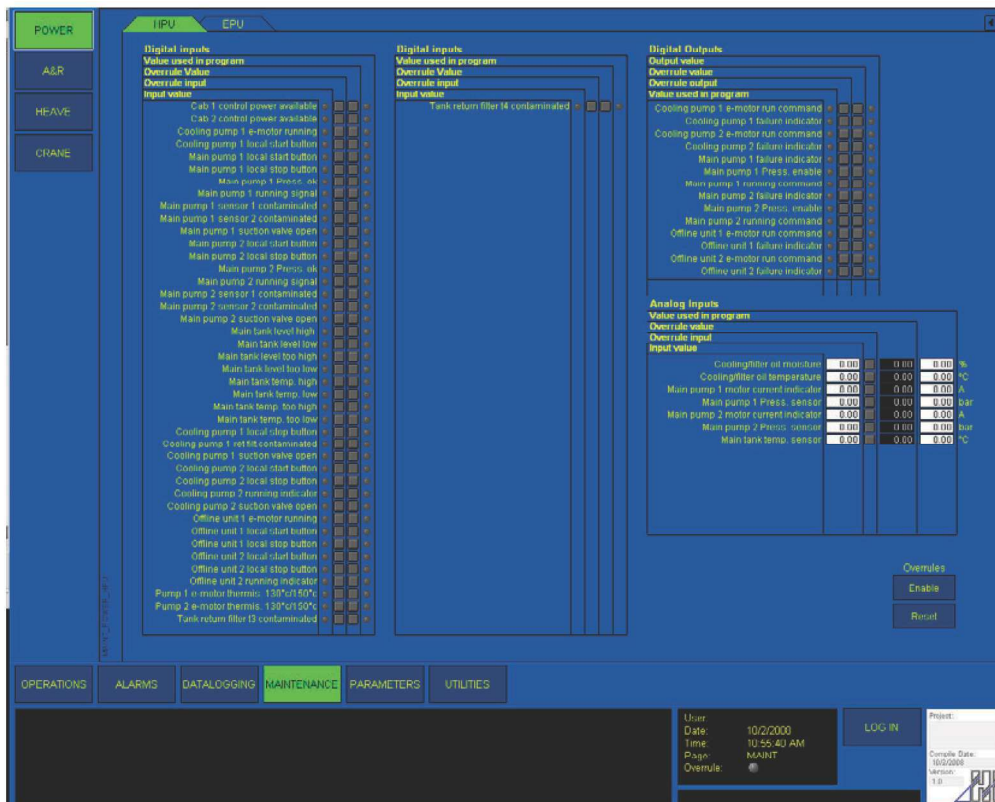


Figure 5-23: MAINTENANCE > POWER > HPU

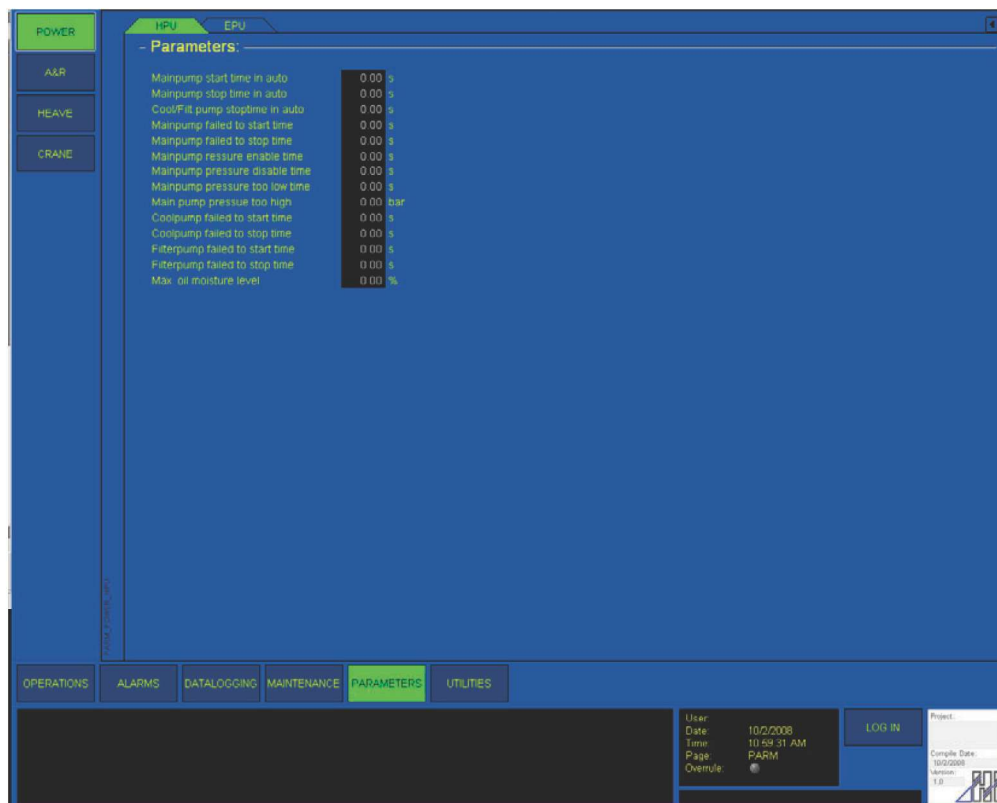


Figure 5-24: PARAMETERS > POWER > HPU

5.3.3 Main pumps

General description

Each of the 2 main pumps is driven by an electric motor. To prevent a large inrush current, there is a hardwired star-delta circuit to start the electric motors. When startup is complete the system signals the PLC by means of the running contact of the delta contactor.

During startup the pump does not feed the hydraulic system to limit the required startup power (disabled by hydraulic valve).

A suction valve, with electric position detection, disconnects the suction line of the pump from the tank. A pressure sensor measures the system pressure. Besides this sensor, a digital contact indicating pressure ok is present. On the outlet side of each pump a coarse filter is mounted, with optical and electrical clogged detection.

Operational description

The main pumps must be started to operate the Heave compensator. The pumps can be started in manual mode or in automatic mode.

To start the motor without load and reduce starting currents the pressure is disabled when starting until the motor is detected running for 5 seconds. Before stopping of the pump the pressure is disabled. The startup and stop sequence is shown in Figure 5-25.

Automatic mode

In automatic mode starting and stopping is controlled by the automatic sequence (see Figure 5-25).

Manual mode

The pump is started by pressing the corresponding button on the local control panel or in SCADA, whichever is in control.

Service mode

Operation is equal to manual mode except that all safeties mentioned in '*Safety conditions and messages*' below are ignored (unless mentioned otherwise). Switching between the system modes is not possible when starting/stopping is active.

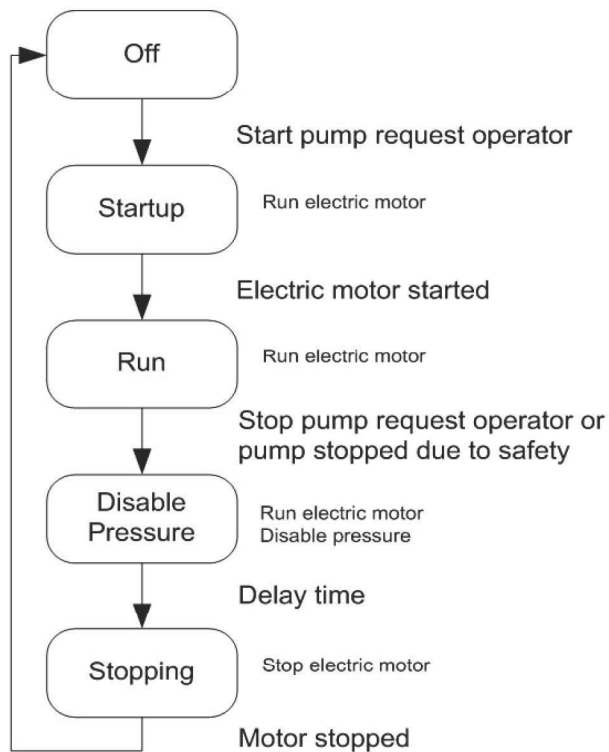


Figure 5-25: Start/stop sequence main pump

WARNING



Between start-up and running of the motor: enable pressure (delay time).

Safety conditions and messages

In service mode the safety conditions are ignored except for the emergency stop.

Running a pump:	Message:
During an emergency stop the motors come to a complete but delayed stop.	By E-stop handling
A thermal relay detects over-current and stops the motor to prevent damage to the motor windings.	Alarm
Once the pump is running the pressure output is checked. If this drops below 220 bar it is assumed that there is a hose rupture and the pump is stopped to oil spillage (after a short delay to filter out peak drops).	Alarm
If the system pressure exceeds 320 bar the pumps are stopped to prevent damaging the system.	Alarm
If the oil level is too low the pump is stopped to avoid cavitation.	Alarm
If the oil level is too high the pump is stopped to avoid tank overflow.	Alarm
If the oil temperature is too low the pump is stopped to avoid cavitation due to high viscosity of the oil.	Alarm
If the oil temperature is too high the pump is stopped too prevent further heating and degrading of the oil and reduced greasing capacity of the oil due to lack of viscosity.	Alarm
If the suction valve is not detected as open, the pump is stopped or prevented to start to avoid cavitation and dry running of the bearings.	Alarm
If no electric supply power is available (circuit breaker off) the pump can not run and is stopped.	Alarm
If the connection to the pumps remote IO unit is lost the pump is stopped (1 remote IO unit per main pump).	Alarm
If the actuation of the motor does not coincide with its running detection the motor is stopped (failed to run / failed to stop)	Alarm

Starting a pump:	Message:
Due to high currents when starting a motor ($2 \times I_{nom}$) a pump cannot be started if another pump is starting.	Inv cmd
Other safety conditions:	
If there is steel pollution detected in the oil (detected by a magnet) an alarm is given. The pump is not stopped, the operator has to decide if the pump is to be stopped. This is also done because this type of measurement frequently causes a false alarm.	Alarm
If the return line oil filter is clogged (detected by pressure difference over the filter) an alarm is given. The pump is not stopped, the operator has to decide if the pump is to be stopped. This is also done because this type of measurement frequently causes a false alarm.	Alarm
If the pump filter is clogged (detected by pressure difference over the filter) an alarm is given. The pump is not stopped.	Alarm
If the tank level reaches the pre-high or pre-low level a warning is given.	Warning
If the oil temperature reaches the pre-high or pre-low level a warning is given	Warning
If the water in oil sensor indicates 95% water, a warning is given	Warning
If one of the filters is contaminated, then the motor is prevented to start.	Alarm/Start inhibit
If no circulation pump is running, then the motor is prevented to start.	Alarm/Start inhibit

Local control

On the HPU cabinet the following controls are mounted:

- Pushbutton “main pump start”
- Pushbutton “main pump stop”
- Signal light “main pump running”
- This light is activated if the motor of the relevant pump is running. (I.e.: the delta-contactor is energized.)
- Signal light “main pump failure”
- Motor current main pump

SCADA

The SCADA screen shows the following data:

- Motor running
- Motor current
- Suction valve status
- Supply power status
- Tank level
- Oil temperature
- Amount of Water in oil sensor
- Amount of Contamination sensor
- Filter status
- Operation mode

5.3.4 Circulation pump

General description

The HPU has two circulation pumps. The circulation pump is a fixed displacement pump driven by an electric motor. The circulation pump ensures the oil flow through the water coolers. A filter, with an visual and electrical clogged detection is mounted between the cooler and the pump. The circulation pump is also used to lubricate the bearings of the main pump.

Operational description

The water cooler is used for cooling the oil. If the oil temperature is too low the circulation pump can be used to heat the oil by circulating it through the system (bypassing the cooler). Only one pump can be active at a time. The second pump acts as a backup.

Automatic mode

In automatic mode starting and stopping is controlled by the automatic sequence (see Figure 5-22.

Manual mode

The pump is started by pressing the corresponding button on the local control panel or in SCADA. In manual mode both control stations operate in parallel.

Service mode

Operation is equal to manual mode except that all safety conditions mentioned in *Safety conditions and messages* (see below) are ignored (except for the emergency stop).

Safety conditions and messages

In service mode safety conditions are ignored.

Running a pump:	Message:
During an emergency stop the motors come to a complete but delayed stop.	By E-stop handling
If no electric supply power is available (circuit breaker off) the pump can not run and is stopped.	Alarm
If the suction valve is not detected open the pump is stopped to avoid cavitation and dry running of the bearings.	Alarm
If the actuation of the motor does not coincide with it's running detection the motor is stopped (failed to run / failed to stop).	Alarm
Only one pump is allowed to run at a time.	Inv. Cmd.

Other safety conditions:	Alarm
If the suction line oil filter is clogged (detected by pressure difference over the filter) an alarm is given. The pump is not stopped, the operator has to decide if the pump is to be stopped. This is also done because this type of measurement frequently causes a false alarm.	Warning

Visualization

Local control panel

On the HPU cabinet the following controls are mounted:

- Pushbutton "start cooling pump"
- Pushbutton "stop cooling pump"
- Signal light "cooling pump running"
- Signal light "cooling pump failure"

SCADA

The SCADA screen shows the following data:

- Motor running
- Suction valve status
- Supply power status
- Filter status

5.3.5 Filter pump

General description

The filter pump is a fixed displacement pump driven by an electric motor. It pumps oil through the oil filter. This filter is for fine filtration (2µm) and has a visual clogging detection only.

Operational description

The filter pump ensures the oil flow through the offline filter.

Automatic mode

In automatic mode starting and stopping is controlled by the automatic sequence (see Figure 5-22 on page 105).

If the pump is disabled it is ignored by the automatic start sequence.

Manual mode

The pump is started by pressing the corresponding button on the local control panel or in SCADA

Service mode

Operation is equal to manual mode except that all safety conditions mentioned in *Safety conditions and messages* (see below) are ignored (unless mentioned otherwise).

Safety conditions and messages

In service mode safety conditions are ignored.

Running a pump:	Message:
During an emergency stop the motors come to a complete but delayed stop.	by E-stop handling
If no electric supply power is available (circuit breaker off) the pump cannot run and is stopped.	Alarm
If the actuation of the motor does not coincide with it's running detection the motor is stopped (failed to run / failed to stop)	Alarm

Other safety conditions:	Alarm
Running of the filter pump is not required for running any of the main pumps. However it is recommended to run the filter pump to clean the oil, therefore a warning is given if any of the main pump is running while the filter pump is not running.	Warning

Visualization

Local control panel

On the HPU panel the following controls are mounted:

- Pushbutton "start filterpump"
- Pushbutton "stop filterpump"
- Signal light "filterpump running"

- Signal light “filterpump failure”

SCADA

The SCADA screen shows the following data:

- Motor running
- Supply power status
- Pump disabled and explanation of disabling

5.4 HEAVE COMPENSATION SYSTEM

5.4.1 Introduction

This document presents a global description of the functions of the Heave Compensation System (HCS).

5.4.2 System description

System Overview

The Heave Compensation System consists of a Passive part and an Active part, see Figure 5-26. The passive system consists of a gas loaded spring system connected to the hoist wire. The spring system extends or retracts depending on the tension in the hoist wire. The passive system in this case comprises a hydraulic main cylinder connected through a medium separator to a battery of pressure vessels charged with nitrogen pressure. By varying the pressure of the gas (by selection of pressure vessels), the system can be adjusted to different static loads. Due to the stiffness of the gas system the tension in the hoist wire changes if the passive cylinder moves in and out.

The passive component

If the load is being lowered to the seabed, the position of the load in relation to the seabed will change because of the ship's heave, pitch and roll motions. As result of this movement the load will also move up and down. The passive system will start to move up and down under influence of the initiated drag and acceleration forces from the load. As these forces always have a phase lag in relation to the position of the load itself and as these forces are dependant on the weight and size of the load the passive system can never compensate for the ships motions. The position of the load in relation to the seabed will therefore vary continuously.

The active component

The Active Heave Compensation system (AHC) adds two so called Active Cylinders to the system. These hydraulic cylinders are mechanically connected to the main cylinder and are controlled by the Active Valve that receives its control signal from the automatic control system.

The active cylinders assist the main cylinder to extend or retract. The major part of the external load (the static component) is supported by the passive main cylinder. The active cylinders only have to overcome the load that is caused by the varying pressure of the nitrogen pressure plus the eventual unbalance in forces from the average nitrogen pressure compared with the average Load.

It will be clear that the nitrogen pressure in the pressure vessels has to be in balance with the average external load of the system. The better this is achieved the less the active cylinders have to compensate.

The Passive versus the Active system

Heave compensation can be used either position controlled or force controlled. Position controlled heave compensation is called AHC. The deck beam end sheave motions are actively compensated. Force controlled heave compensation is called Passive Constant Tensioning (PCT). In this mode no control systems are active and zero power is consumed.

With AHC the real-time signal of the Motion Reference Unit (MRU) is used as an input signal. In response to this signal the hydraulic cylinder takes in or pays out wire to keep the load at a constant elevation above the seabed when in AHC. The main hoisting load is compensated by the Passive Cylinder of the HCS. During active heave compensation a separate cylinder is used to move the large cylinder. By varying the pump flow, the active cylinder extends or retracts the Passive Cylinder.

The input signal received from the sensor is used to determine the required retraction or extension. Since the main part of the force is compensated by the large cylinder only a small active controlled cylinder is needed. This reduces the power demand on the ships power system significantly. Absolutely vital for proper functioning of any active compensation system is that it uses a real time signal and therefore does not have to rely on any wave or motion prediction method.

Measurements show that the vertical motions of the load are reduced to approximately 10% of the original heave motion.

5.5 PRESSURE VESSEL UNIT

5.5.1 Introduction

This section presents a global description of the functions of the Pressure Vessel Unit (PVU) for the Heave Compensation System.

5.5.2 System description

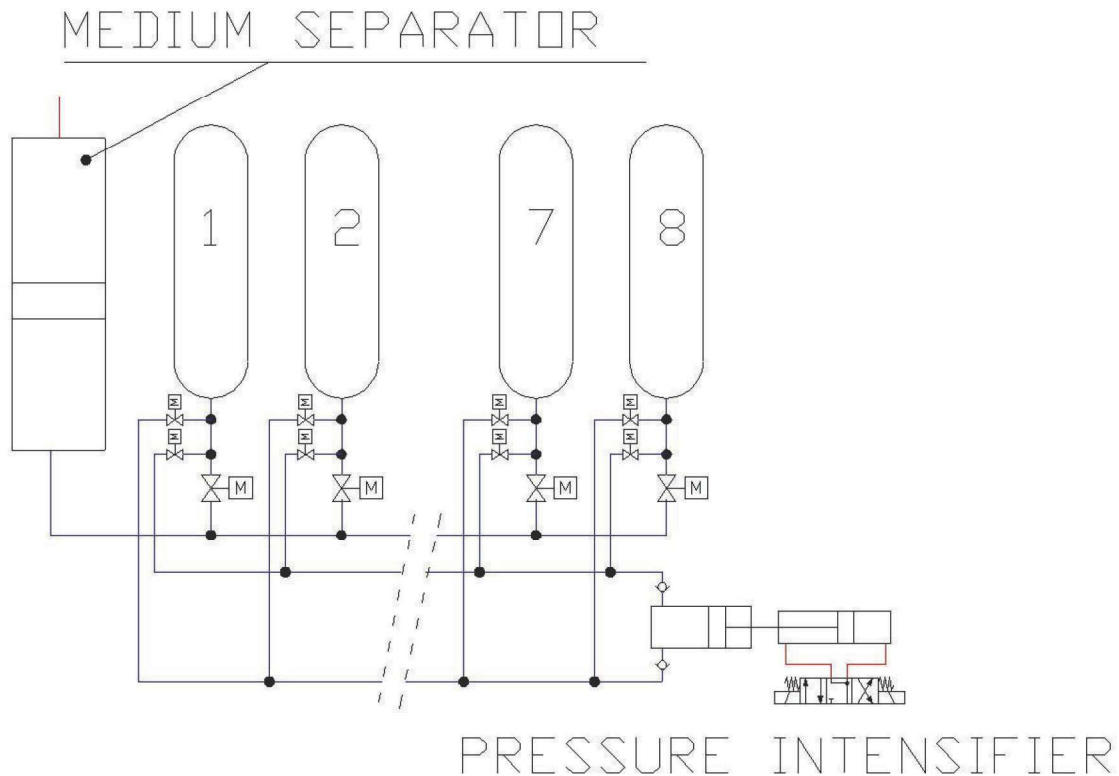


Figure 5-26: Passive versus Active system

The N2 gas pressure system

The N2 gas pressure system consists of a number of sets of two vessels each. Each set can be connected to or disconnected from the medium separator e.g. the main cylinder. If there is an odd number of vessels required, then the last vessel is operated as stand-alone (not combined into a set of two.)

Each set of pressure vessels is pre-charged at a different nitrogen pressure. The average nitrogen pressure in the main cylinder can be adjusted by connecting pressure vessels to the system that is pre-charged at higher or lower pressures.

This adjustment of the gas pressure is necessary when the load of the heave compensator changes. If for instance a load is lowered to the seabed, at first the total load will increase due to increasing length and weight of the wire but later on the load will decrease if the weight of the load is transferred to the seabed.

The change in gas pressure in the PHC system can normally be achieved by shifting gas from other pressure vessels which are pre-charged at higher or lower pressures. This can be done with remotely operated valves.

Re-charging pressure vessels

The individual pressure vessels can be re-charged at different gas pressures with the use of the supplied Pressure Intensifier, see figure below.

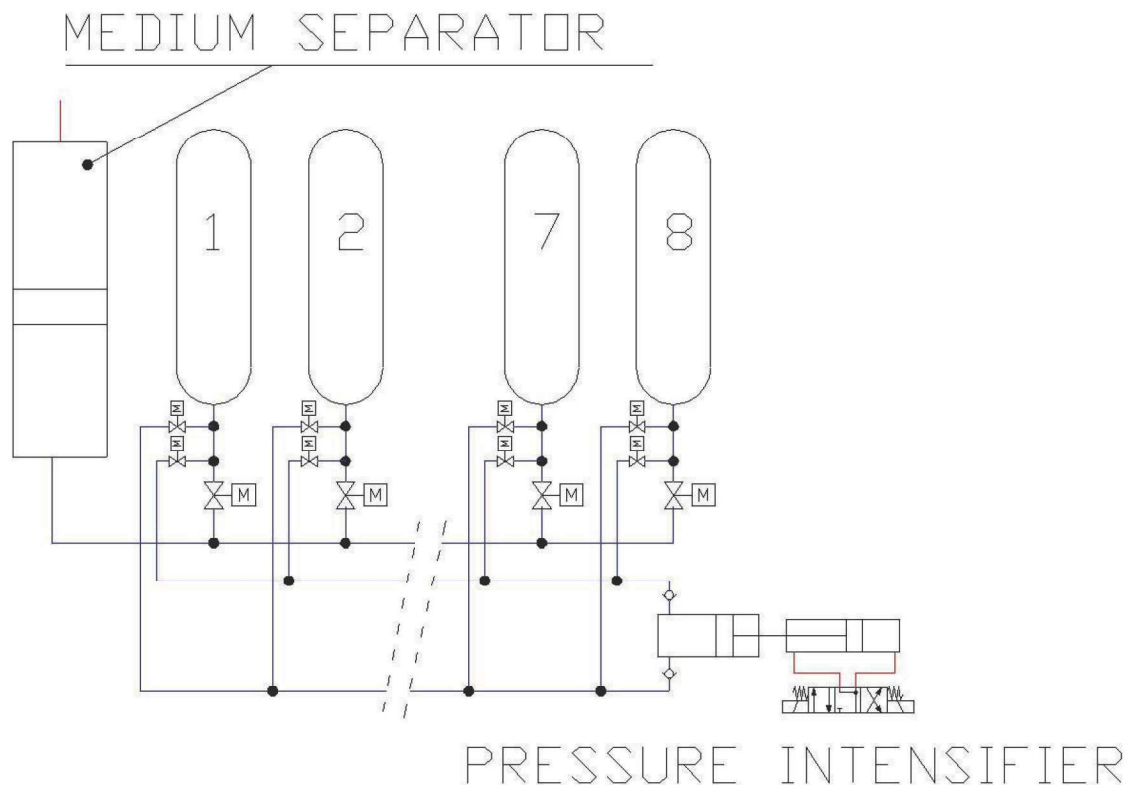


Figure 5-27: Pressure intensifier to charge vessels (schematic)

Each vessel set can be connected to the Medium Separator or to the suction or discharge connection of the Pressure Intensifier. All connection valves are remotely operated valves (controlled by the PLC). All pressure readings are done via pressure transmitters. This means that the re-charge of a pressure vessel can be done from a SCADA station or control system.

If the passive and/or active systems are in operation the pressure intensifier can be used to charge pressure vessels at higher pressure levels. The pressure Intensifier is a single or dual stage linear intensifier. This device is driven by a hydraulic cylinder. The pressure in the vessel that is connected to the HP-line will increase while the pressure in the vessel that is connected to the LP-line will decrease.

Operational procedures

The active heave system will be used when lowering or hoisting loads from/to the seabed. The active part of the Heave Compensator can only be used when the HPU for the heave compensator is running.

System Modes

The PVU can be started in: automatic, manual or service mode.

Automatic mode

In automatic mode the open/close commands are received by the sequencer programmed for each pressure vessel set. The automatic mode is in operation if the automatic sequence command is set by the operator.

Manual mode

Opening and closing of valves are initiated manually from the SCADA system.

Service mode

Operation of the valves is identical to manual mode, except that safety checks by the PLC are bypassed.

Control Locations

The AHC/PVU can be operated and monitored from the control desk and SCADA. On the control desk for the active heave the following buttons are implemented:

- key switch for heave compensator
- button fast gas release
- button increase pressure
- button decrease pressure
- button 'activate next step' (optional)
- button passive heave on/off
- button active heave on/off

5.5.3 General system

Operational

The PVU system is part of the active heave compensation system.

The PVU system is operational if the following conditions are met:

- System is selected ON
- Remote IO unit(s) OK
- No emergency stop
- HPU is running

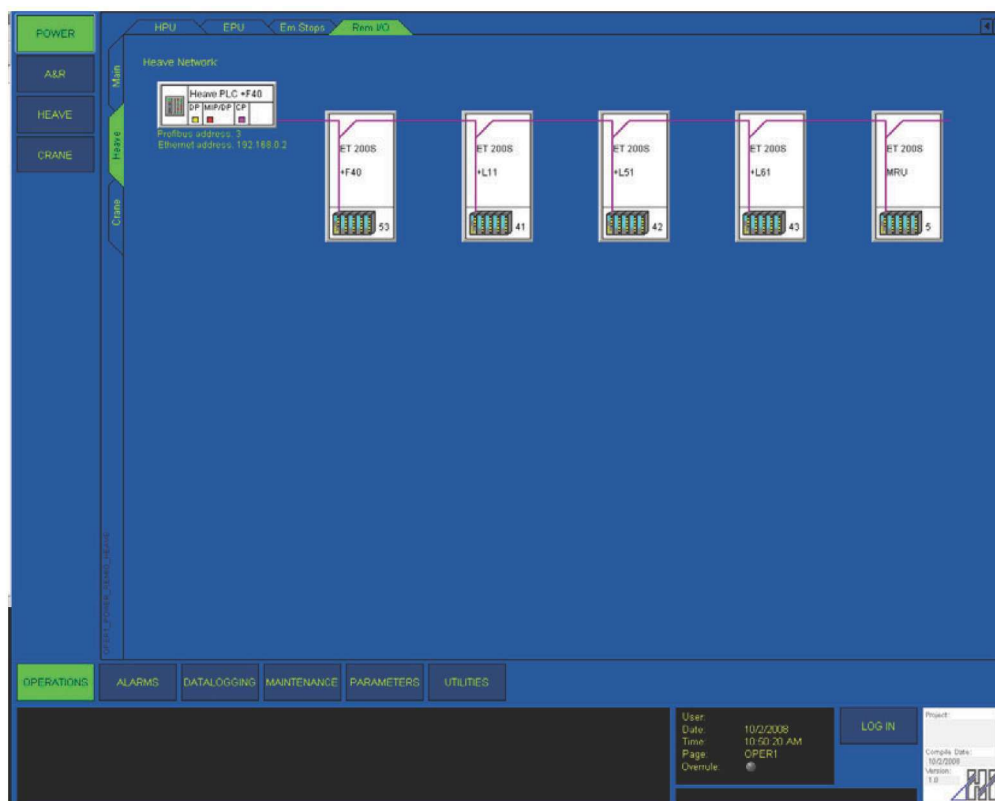


Figure 5-28: OPERATIONS > POWER > REMOTE I/O > HEAVE

Operating modes

The active heave compensation system has the following modes:

- Idle mode
- Passive heave compensation
- Active heave compensation

The valves and the charge pump can have the following modes:

- Manual mode
- Automatic mode
- Service mode

Only a complete vessel section can be placed in automatic/manual/service mode.

Control location / handover

The AHC system can be operated from a remote operator panel and from the SCADA system.

Activating the passive and/or active heave compensation is being done from the remote operator panel.

Alarm handling

An alarm is generated for each of the following situations:

- detectable sensor failure (possible for 4-20mA, SSI, and Namur sensors).
- detected sensor discrepancy (lock & unlock sensor seen at same time etc.)
- detected actuation inconsistency (fan is commanded to run but not running and vice versa, etc.)

Invalid commands are generated for each interlock which prevents an action unless this interlock is an alarm or warning which already generates a message. To avoid unnecessary alarms and warnings, each alarm and warning is only activated when the remote IO for that system is available.

Visualization

Operator panel

The following controls are mounted on the remote operator panel.

- key switch for heave compensator
- button fast gas release
- button increase pressure
- button decrease pressure
- button 'activate next step' (optional)
- button passive heave on/off
- button active heave on/off

SCADA

The AHC will have a dedicated operator panel. Manual control is being done from SCADA (see Figure 5-29). Figure 5-30 shows the parameters screen for the heave compensation system. The SCADA maintenance screen for the AHC is shown in Figure 5-31.

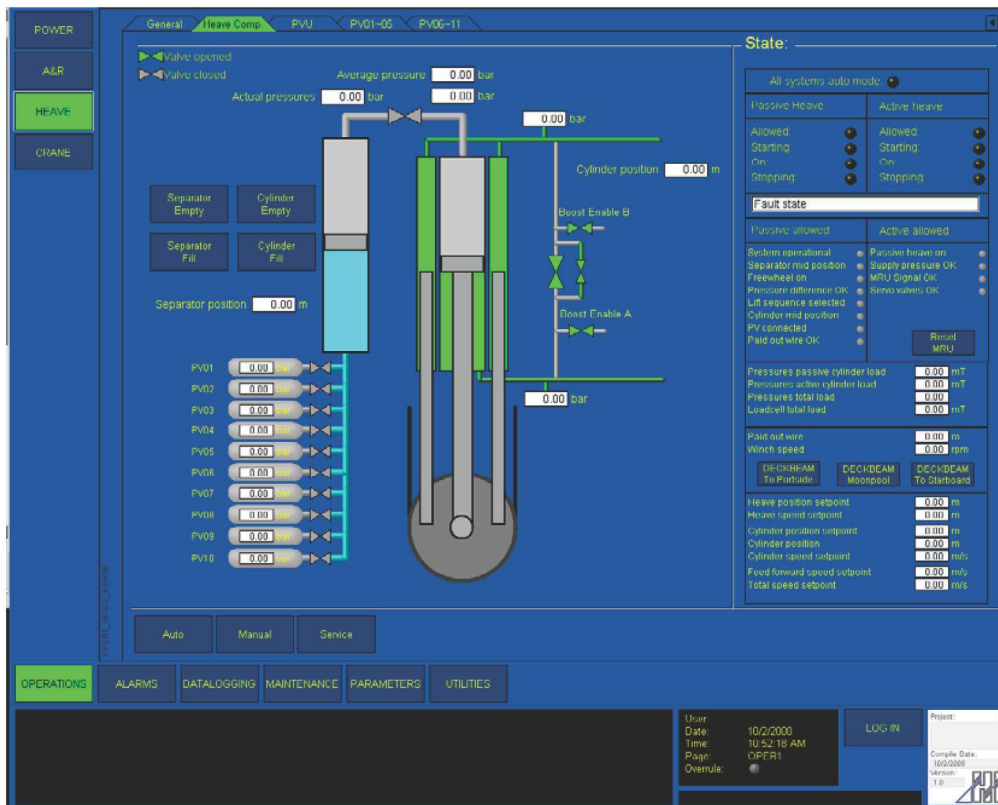


Figure 5-29: OPERATIONS > HEAVE > HEAVE COMPENSATION



Figure 5-30: PARAMETERS > HEAVE > HEAVE COMPENSATION



Figure 5-31: MAINTENANCE > HEAVE > HEAVE COMPENSATION

5.5.4 Pressure Vessel Unit

General description

The pressure vessel unit consists of a number of sets of two vessels. A HP ball valve and a LP ball valve connects the vessel-set to the HP-line and the LP-line of the PIU. These ball valves are hydraulically controlled by a normally closed 4/2 valve. The HP and LP lines are used to set vessel-sets on a required pressure.

The vessel section can be connected to the medium separator with two large ball valves. These ball valves are hydraulically operated by a 4/3 valve. The open and close position of each ball valve is detected by an end switch.

Each vessel section is equipped with two analogue pressure indications (one for each vessel).

Operational description

The pressure vessel unit is used to charge the nitrogen part of the medium separator to the requested pressure. An engineer has to calculate the required pressures in the different PVUs and select the correct PVUs for operation. In automatic mode the control system will calculate the pre-set values for the PVU. An engineer has to check this. To set the PVUs on the required pressure, automatic or manual mode can be used.

Each PVU can be selected for automatic/ manual/ service mode separately. Service mode is only allowed when the passive main valve is closed.

When an alarm regarding the position sensors is detected, this will be indicated by red flashing of the indication lights at the SCADA system;

When a valve is traveling from open to close or vice versa, this is represented by flashing of the requested position indication light;

The HP and LP-line valves item will be actuated when the requested position has to be opened. When the requested position has to be closed the valves will not be energized (normally closed valves)

The separator valves item will be energized when the large ball valves item 0.10, Ref. [1] are requested opened or closed. Once the opened or closed position is detected the valve will be 1 second delayed de-energized.

Automatic mode (optional)

In automatic mode the opening and closing commands are received by the automatic sequences for each vessel section it will be controlled if the automatic sequence command is allowed.

Manual mode

The valves are opened and closed by pressing the corresponding buttons in SCADA (see Figure 5-32 until Figure 5-34).

The activation of a command becomes active on the rising edge of a command.

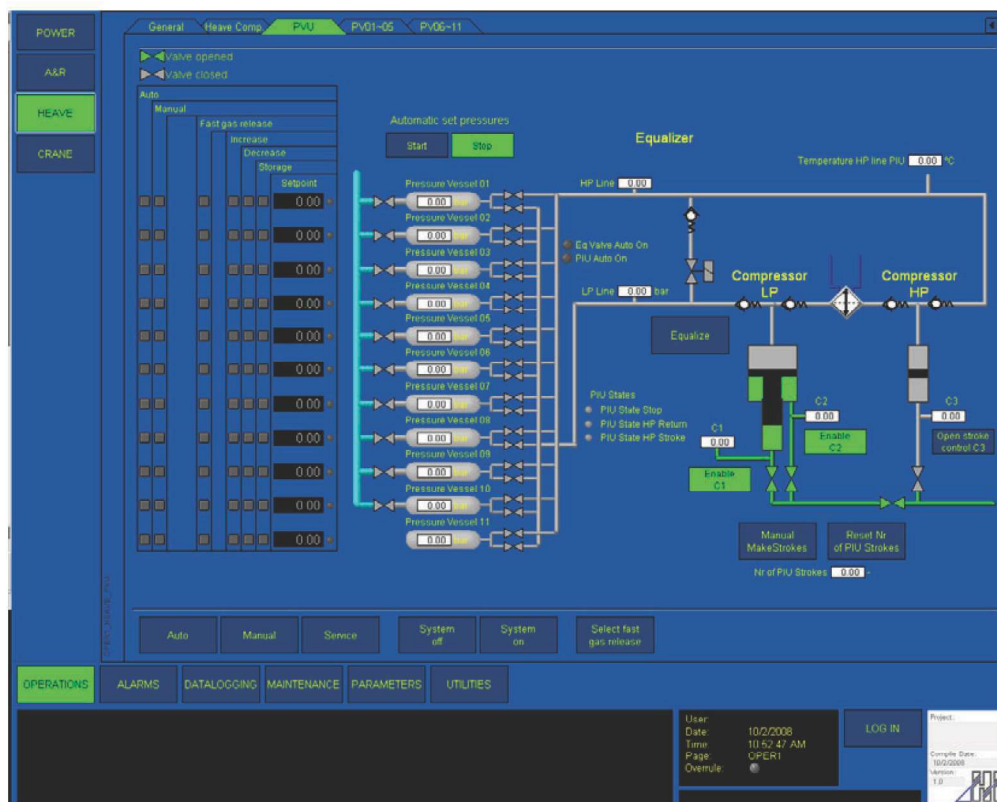


Figure 5-32: OPERATIONS > HEAVE > PVU



Figure 5-33: OPERATIONS > HEAVE > PRESSURE VESSELS 01 ~ 05

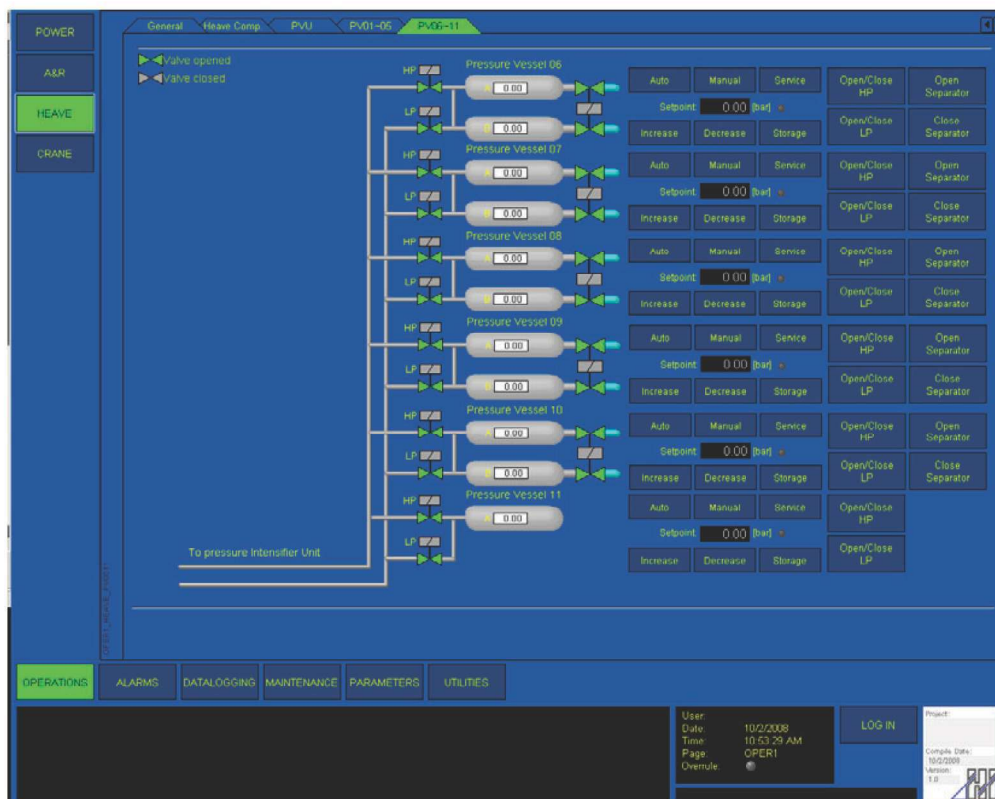


Figure 5-34: OPERATIONS > HEAVE > PRESSURE VESSELS 06 ~ 11

Service mode

Operation in service mode is equal to manual mode except that all safety's mentioned in '*Safety conditions and messages*' below are ignored (unless mentioned otherwise). Figure 5-35 shows the maintenance screen for the pressure vessel unit. The SCADA maintenance screens for the separate pressure vessel sections are shown in Figure 5-36 and Figure 5-37.

Figure 5-38 shows the parameters screen for the pressure vessel unit.

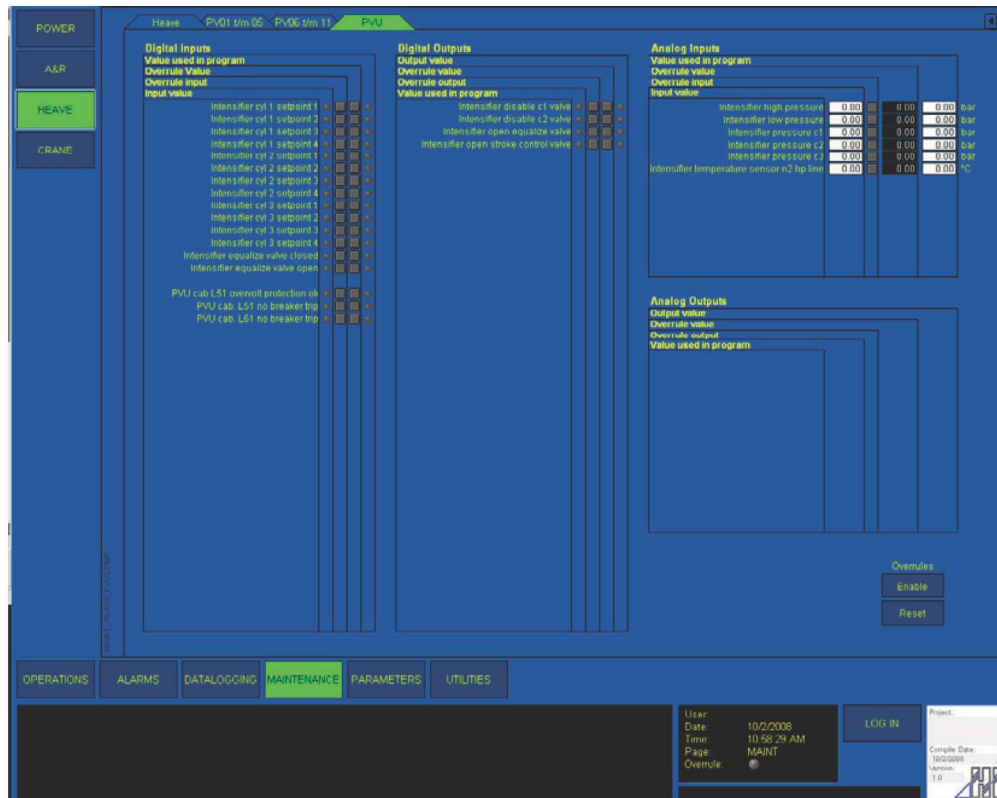


Figure 5-35: MAINTENANCE > HEAVE > PVU

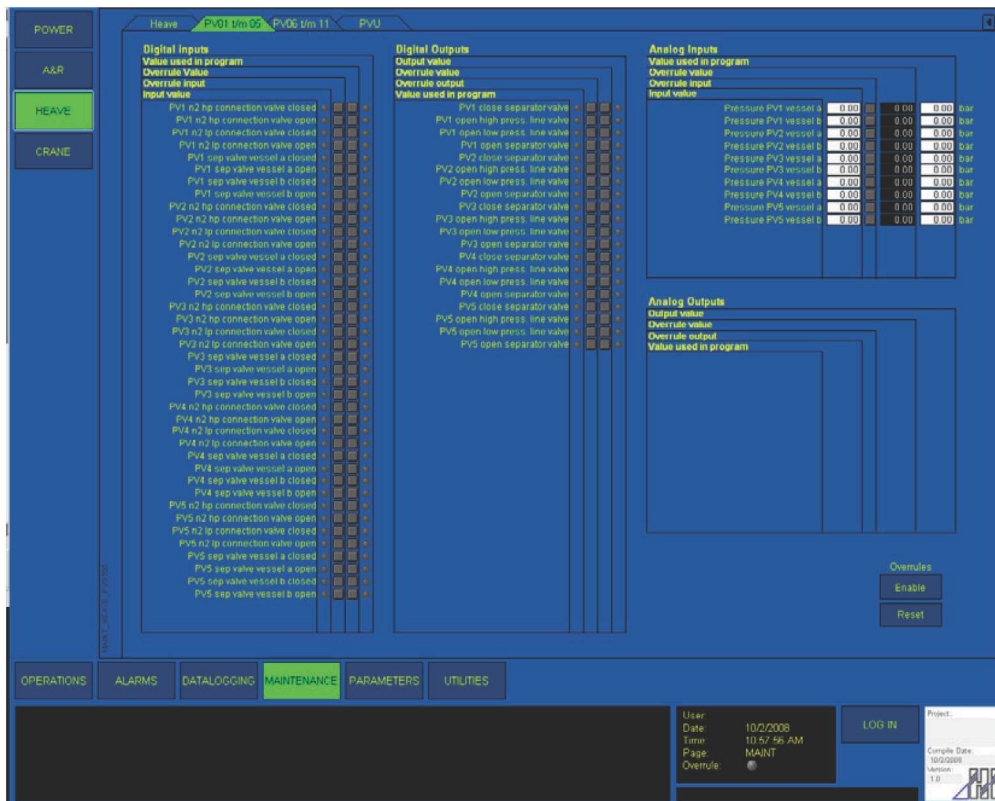


Figure 5-36: MAINTENANCE > HEAVE > PRESSURE VESSELS 01 ~ 05



Figure 5-37: MAINTENANCE > HEAVE > PRESSURE VESSELS 06 ~ 11

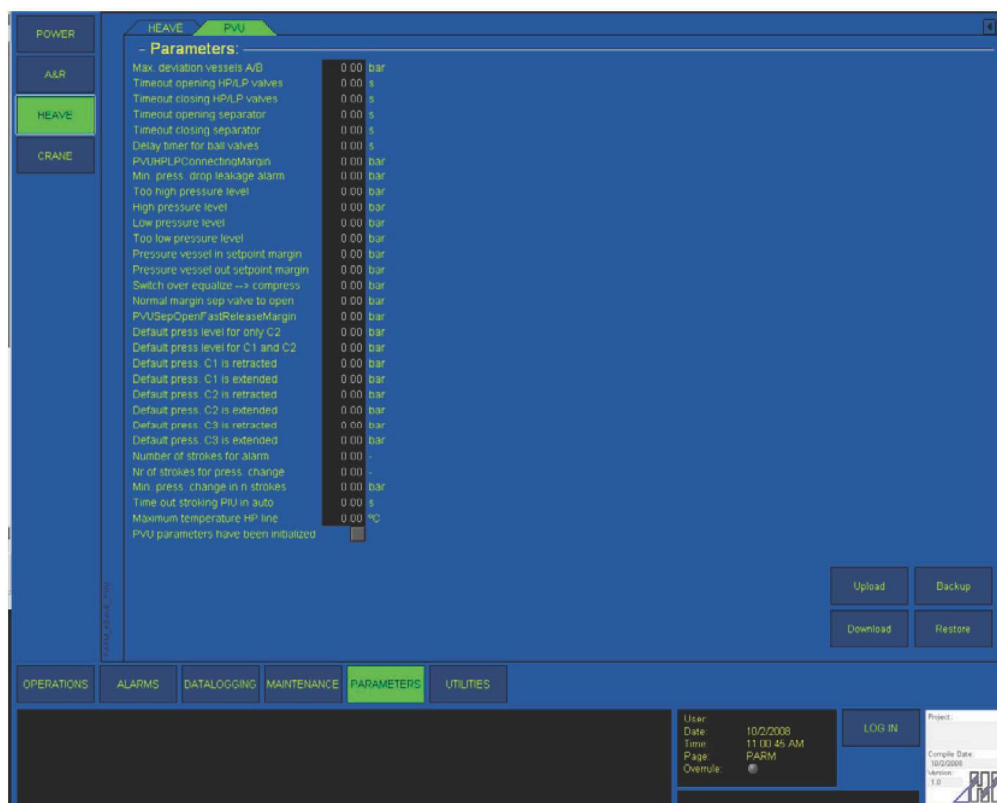


Figure 5-38: PARAMETERS > HEAVE > PVU

Safety conditions and messages

General	Message:
When the pressure difference is more than 10 bar between the two vessels from a section this either indicates a closed hand-valve item or a fault pressure sensor. No operation is possible on this vessel unit.	by E-stop handling
When all valves of one PVU are closed the amount of gas must stay the same. When the pressure in a PVU drops too much a leakage detected alarm is generated. Because of pressure variations caused by temperature variations this margin is 30 bar.	Alarm
When all valves of one PVU are closed the amount of gas must stay the same. When the pressure in a PVU drops too much a leakage detected alarm is generated. Because of pressure variations caused by temperature variations this margin is 30 bar.	Alarm

HP/LP-line valves	Message:
When the open and close signals of the valves are detected at the same time, then the position of the valve is undefined. No operation for that PVU is allowed.	Alarm
When the requested position is not reached within 5 seconds after command, the requested command is stopped. The valve is de-energized.	Alarm
Once the requested position has been detected and lost without any command, the opened/closed detection lost alarm is generated immediately and the valve is de-energized.	Alarm

HP/LP-line valves	Message:
It is not allowed to open the HP and LP line valves of one PVU at the same time. Equalizing of the HP-line and LP-line is done using the flow-reducer with the equalizer valve.	Inv. Cmd.
Because the flow from one vessel section to another vessel section has to be limited to prevent damage to the ball valves it is not allowed to connect more than one vessel section to the HP or the LP line.	Inv. Cmd.
To prevent damage to the PIU valves, it is not allowed to connect a vessel section with a higher pressure to the LP-line than the vessel section which is connected to the HP-line.	Inv. Cmd.
To prevent damage to the PIU valves, it is not allowed to connect a vessel section with a lower pressure to the HP-line than the vessel section which is connected to the LP-line. the max. allowable difference is 8 bar.	Inv. Cmd.
When a LP or HP-line valve is opened the measurement of the pressure vessel with the measurement in the LP- and HP line must be within a difference of 5 bars. When the difference > 5 bars an alarm is generated. Because the PIU or the equalizer valve affects pressure differences between these measurements the alarm will not be displayed when the equalizer valve is opened or the PIU is in use.	Alarm

Separator valves	Message:
When the position of the valve is not detected opened or closed. It is not clear in which position the valve is at that moment. No operation for that PVU is allowed. The operator has to give a command to energize the valve to open or close.	Alarm
When open and close is detected at the same time. It is not clear in which position the valve is at that moment. No operation for that PVU is allowed.	Alarm
When the requested position is not reached within 10 seconds after command. The requested command is stopped. The valve is energized valve to the last detected position.	Alarm
Once the requested position has been detected and lost without any command, the opened/closed detection lost alarm is generated immediately the valve will be energized to the requested position at that moment.	Alarm
To prevent damage to the valves it is not allowed to connect a PVU to the separator when there is already a PVU connected to the separator and the pressure difference between the connected PVU and the PVU which is requested to be connected is > 10 bar. For the fast gas pressure release function it may be necessary to connect a PVU with a lower pressure to the separator where already a PVU is connected to. In this case the pressure of the PVU which is requested to be connected can be 50 bars lower than the PVU which is already connected to the separator	Inv. Cmd.

Visualization

The SCADA screen shows the following data:

- Position of the valves
- Pressures in the vessels
- Operation mode
- Safety- and other messages
- Buttons for manual commands

5.5.5 Equalizer valve (EV)

General description

The equalizer valve (EV) is a hydraulically controlled ball valve which realizes flow from the HP- to the LP-line. The ball valve is controlled by a 4/2 directional control valve. The ball valve is equipped with an open and a closed indication switch.

Operational description

The EV equalizes the pressure between the vessel section which is connected to the HP-line and the vessel section which is connected to the LP-line.

The equalizer valve will be energized when the ball valve is requested opened to realize a flow from the HP-line to the LP-line. The valve will be energized as long as the opened position is requested.

Automatic mode

In automatic mode opening is controlled by the automatic sequence.

Manual mode

The valve is opened by pressing the corresponding buttons in SCADA.

Service mode

Operation is equal to manual mode except that all safety's mentioned in '*Safety conditions and messages*' below are ignored (unless mentioned otherwise).

Safety conditions and messages

Opening/closing	Message:
When the open and close position is detected at the same time, then the position of the valve is undefined No operation for the EV is allowed.	Alarm
When the requested position is not reached within 3 seconds after an open/close command the requested command is aborted. The valve will be de-energised.	Alarm
Once the requested position has been detected and lost without any command, the opened/closed detection lost alarm is generated immediately and the valve is de-energized.	Alarm
Opening the EV is not allowed when the PIU is active.	Inv. Cmd.

Visualization

The SCADA screen shows the following data:

- Position of the valve
- Operation mode
- Safety and other messages

5.5.6 Pressure Intensifier Unit (PIU)

General description

The heave system is equipped with a PIU to charge gas into a selected vessel unit. The compressor consists of a high pressure stage and a low pressure stage. Both the high and low pressure stages are operated by hydraulic 4/2 valves.

The PIU consists of a first stage unit and second stage unit. The first stage unit can be driven by two individually controlled hydraulic cylinders C1 and C2. The second stage unit is driven by a single hydraulic cylinder C3. A single stroke of the PIU is controlled by a 4/2 valve "Stroke Control Valve". The driving cylinders C1 and/or C2 of the high volume unit can be disabled with individual hydraulic 4/2 valves.

The effectiveness of the driving units C1 and/or C2 depends on the available hydraulic inlet pressure of the PIU.

Each drive cylinder compartment is equipped with analogue pressure reading. This reading is for displaying on SCADA and to determine if the corresponding stage is extended or retracted.

Operational description

The PIU can be connected to a vessel unit by connecting the vessel sections to the HP- and LP-lines. To displace gas from one vessel section to a second vessel section, the vessel section to be discharged has to be connected to the LP-line and the vessel section to be charged to the HP-line.

If the pressure measurements indicate the pump sections of the PIU are in one of the extreme positions, this is indicated by the cylinder position on SCADA.

A new target position request will only be activated if the pump is in an extreme position, not being the target position, or if the pump has not been in one of the extreme positions longer than 20 seconds. The charge pump is only allowed to run if at least one HP valve and one LP valve is opened.

The pressure settings for the PIU can be changed via SCADA. Resetting this will set back the default values of the pressure settings.

Automatic mode

In automatic mode starting and stopping is controlled by the automatic sequence.

The compression cycle is active for as long compression is allowed or till the required pressure in the target vessel section is reached.

Controlling the complete PIU or a part of it, will be based on the inlet pressure of the PIU. To prevent too much switching a hysteresis will be used.

One PIU cycle is defined as a full single extending stroke of the cylinders C1, C2 and C3. The retracting of these cylinders is always performed by the gas pressure itself. The extended stroke of a cylinder C1, C2 or C3 is detected by a high hydraulic pressure > 280 bar in the particular cylinder compartment. The retracted position of a cylinder C1, C2 or C3 is detected by a low hydraulic pressure < 10 bar at the particular cylinder compartment.

The selection of the Pump Sections C1, C2 and C3 that can be used during one pump cycle depends on the input pressure to the PIU, see table below.

Pressure reading	Condition (default values)	Action
2.09A	< 10 bar	PIU may not be operated
2.09A	< 32 bar	Only C1 and C3 are to be used
2.09A	32 < 45 bar	Only C2 and C3 are to be used
2.09A	> 45 bar	C1, C2 and C3 are to be used
2.09A	> 280 bar	PIU may not be operated

A pump cycle is being activated by energizing valve 2.03A. This valve always activates cylinder C3 and depending on the allowable function for C1 and/or C2 it also activates C1 and/or C2. The cylinders C1 and C2 can be enabled with respectively valve 2.03B and 2.03C.

The end positions of the cylinders can be detected by individual pressure switches for each cylinder, see table below:

Cylinder	Position	Pressure reading	Condition (default values)
C1	Extended stroke	2.09C	< 20 bar
	Retracted stroke	2.09C	> 280 bar
C2	Extended stroke	2.09D	< 20 bar
	Retracted stroke	2.09D	> 280 bar
C3	Extended stroke	2.09B	< 20 bar
	Retracted stroke	2.09B	> 280 bar

Manual mode

In manual mode the PIU can be controlled by semi-automatic or full manual.

For semi-automatic there will be one full compression cycle consisting of 1 hydraulic driven extending stroke and a gas driven retracting stroke.

In manual the valves are directly controlled by pressing the corresponding buttons on the SCADA screen.

The PIU is operated by pressing the corresponding button in SCADA. The operator is responsible for operating the 4/2 valves for the PIU.

The operator is responsible for controlling the right 4/2 valves (= active cylinders C1, C2 or C3) to achieve the needed outlet pressure.

Service mode

Operation is equal to manual mode except that all safety's mentioned in '*Safety conditions and messages*' below are ignored (unless mentioned otherwise).

Safety conditions and messages

Running the PIU:	Message:
During an emergency stop the 4/2 hydraulic valves which control the compressor will no longer be activated.	by E-stop handling

Running the PIU:	Message:
To prevent an uncontrolled situation, compression is not allowed when a pressure sensor is faulted.	Alarm
To prevent unnecessary high pressure in the system, compression is not allowed if no HP and LP valve is opened.	Inv. Cmd.
The compressor may only be used when the equalizer valve is closed.	Inv. Cmd.
Compression is stopped if the pressure before the low pressure section is less or equal to 10 bar, item 2.09A.	Alarm
If the pressure from the selected vessel sections is not changing after 25 full strokes a message is displayed	Warning
The number of strokes in automatic mode is counted. When the counted compression cycles of 2 vessel section becomes too high a warning is generated. The operator has to take the correct action.	Warning
When the measured pressure in the compressor is not the same as the connected PVU this indicates a hand valve closed or a sensor fault. Compression is not allowed.	Alarm
Compression is stopped if the pressure after the PIU is higher then 280 bar	Inv. Cmd.
To prevent damage to the seals a temperature measurement in the outlet of the second stage is added. When the temperature is too high the PIU is stopped and an alarm is generated.	Alarm

Visualization

The SCADA screen shows the following data:

- Compressor status
- Measured pressures
- Operation mode
- Safety and other messages

5.5.7 Charge/drain cycles

General description

In both AHC-mode and in PHC-mode the gas pressure is used as a static compensation of the submerged weight of the load in the main hook. The capacitance of the gas spring depends on the gas pressure and on the available volume of gas that can be controlled by connecting several vessel sections in parallel.

The pressure in the connected vessels sections must correspond with the submerged weight of the load in the main hook prior to activating either the active heave compensation system or the passive heave compensation system. The number of active vessels sections necessary for operation must be selected based on the required capacitance. Light loads or loads that are not subjected to considerable drag forces require a high capacitance (weak spring) while loads that are subjected to large drag forces require a low capacitance (stiff spring) in order to prevent that the piston is driven into its buffers.

For certain types of operation it may be necessary that a quick switchover between two pressure levels must be possible. For that reason, the gas vessels can be subdivided into a high-pressure and a low-pressure section. This subdivision must be set-up by the operator.

For a complete overview the vessels can be divided into five types:

1. Operational vessels:

Vessels that are connected to the separator.

2. Increase vessels:

Vessels for increasing the pressure in the operational vessels.

3. Decrease vessels:

Vessels for decreasing the pressure in the operational vessels.

4. Storage pressure vessels:

Vessels of which the pressure level is irrelevant.

5. Fast gas release vessels:

Vessels that are appointed as fast gas release vessels will be connected to the operational vessels when the fast gas release function is enabled and the relating button on the desk is pressed.

For each operation at least one section of vessels must be appointed as operational vessel (connected to the separator). Assignment of increase- and decrease-vessels is not obligatory. Fast gas release sections are needed for a quick change-over from the operational vessels to a low pressure when a load is being lifted from the seabed.

Charging gas can be established by the PIU. Gas can also naturally flow from a pressure vessel unit with a high pressure to a pressure vessel unit with a lower pressure. This is being done by using the equalize valve.

Operational description

When using the PIU to charge gas to a vessel unit, gas is shifted from the pressure vessels which are connected to the HP and LP lines. In automatic mode the discharge / charge cycle will be controlled without operator interference. Due to the limited oil pressure (typ. 270 bar), the maximum gas pressure that can be achieved using the compressor is limited to that pressure.

Charging / discharging of vessel sections can also be accomplished by letting gas flow from a section with a higher pressure to a section with a lower pressure. Natural flow of gas speeds up charging of the HP-bottles and is therefore beneficial. The equalizer valve will be used to enable natural gas flow.

Because the PVU is a closed system, gas can only be shifted between vessel sections.

Charging/draining of the operational vessels is also possible if the vessel section is not connected to the medium separator.

Setpoint values will be effectuated within an accuracy of ± 5 bar hysteresis will be used to prevent vessels being in the setpoints one time and without any action not being in the setpoints.

The equalizer valve will be used for the natural gas flow.

The PIU pump will be used to charge gas from a vessel section with a lower pressure to a vessel section with a higher pressure.

Multiple vessel sections can be selected for the automatic sequence.

Automatic mode (optional)

In automatic mode charging and/or draining is controlled by the automatic sequence;

Each vessel section in automatic mode is brought to the required pressure by the sequence illustrated in Figure 5-39.

When a vessel is selected and it is not in its setpoint the choice will be made if the selected vessel must be charged or discharged.

When the vessel must be charged, a vessel will be automatically selected that has to be discharged. When no vessel is selected to be discharged a storage vessel will be used.

According to the actual pressures in the vessel sections the selection is made which vessel will be connected to the HP line and which vessel will be connected to the LP line. This is illustrated in Figure 5-40. The vessel sections are not connected to the HP and LP line simultaneously for the safety-interlocks mentioned in Req. 11.6 and 11.7

When the HP and the LP valves are opened, the automatic equalize or automatic compress command is sent to these systems.

The setpoint for each PVU must be $20 < \text{setpoint} < 270$ bar

All the PVU's which need to be brought to a required pressure have to be in automatic mode, including the Storage-Vessels. When a vessel is in manual mode this vessel section will not be used for the automatic sequence.

When gas is shifted to a pressure vessel using the PIU the gas temperature will rise. Because of the temperature the vessel where the gas is shifted to gives the signal 'in setpoint' when the upper limit of the hysteresis is reached. After a time the temperature of the gas will drop and the pressure vessel will still be within its setpoint.

When gas is shifted to a pressure vessel using the EV the gas temperature will drop. Because of the temperature the vessel where the gas is shifted to gives the signal 'in setpoint' when the lower limit of the hysteresis is reached. After a time the temperature of the gas will rise and the pressure vessel will still be within its setpoint.

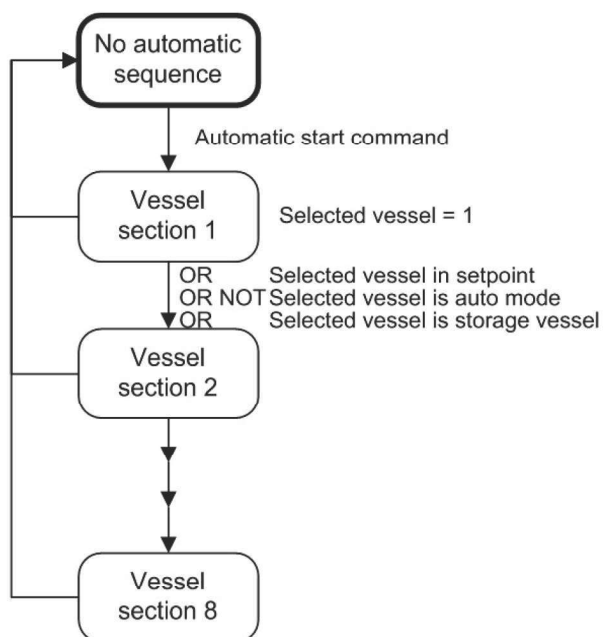


Figure 5-39: Automatic charge / discharge cycle

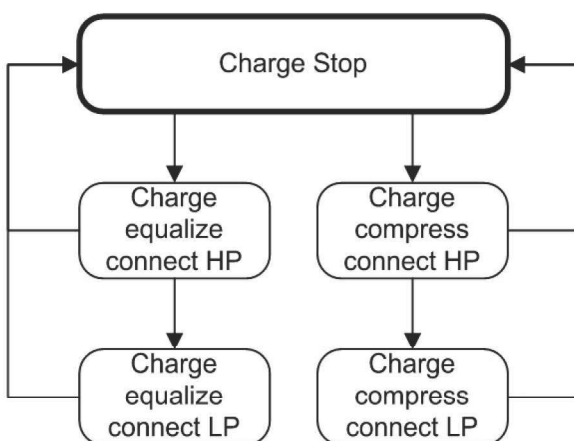


Figure 5-40: Charge equalize / compress choice

Manual mode

Charging and draining in manual mode requires one PV connected to the HP line and one PV connected to the LP line.

In manual mode the compressor and the equalizer are activated by the operator using the switch on the control desk, or giving the command on SCADA.

Charging and draining is controlled by the operator i.e. charging / draining will not be stopped on setpoints.

Safety conditions and messages

General	Message:
The automatic sequence will be stopped when an E-stop occurs.	by E-stop handling
Manual charging and draining is stopped when one of the two selected PVU pressures > 270 or < 20 bar.	Inv. Cmd.
Each pressure vessel will determine for that system if the required automatic sequence actions are allowed	-
When the automatic sequence is active and the EV or the PIU does not work in 20 seconds an automatic mode time-out is generated	Alarm
In automatic mode the control system will look for a vessel to get gas from, or put gas into. when no vessel can be found an alarm will be generated and the automatic sequence will be stopped.	Alarm
The automatic sequence will be stopped when an E-stop occurs.	by E-stop handling

Visualization

The SCADA screen shows the following data (see Figure 5-41 until Figure 5-43):

- Pressure setpoints
- Actual pressures
- Automatic mode/manual mode
- Actual status
- Operation mode
- Safety and other messages

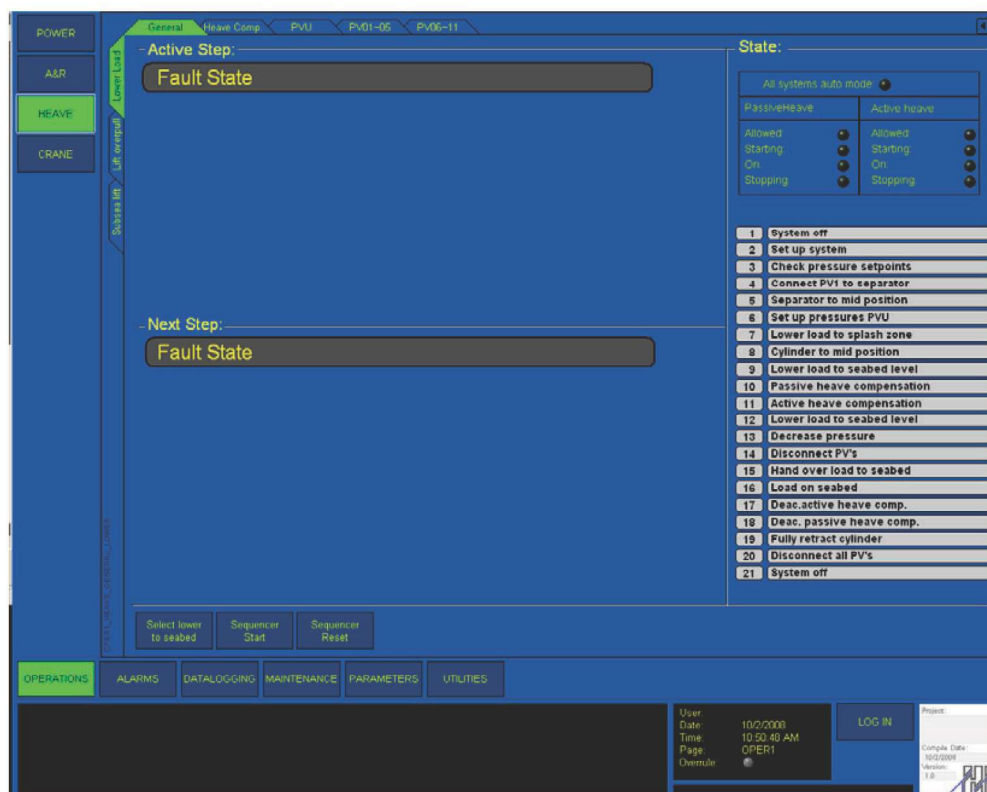


Figure 5-41: OPERATIONS > HEAVE GENERAL > LOWER LOAD

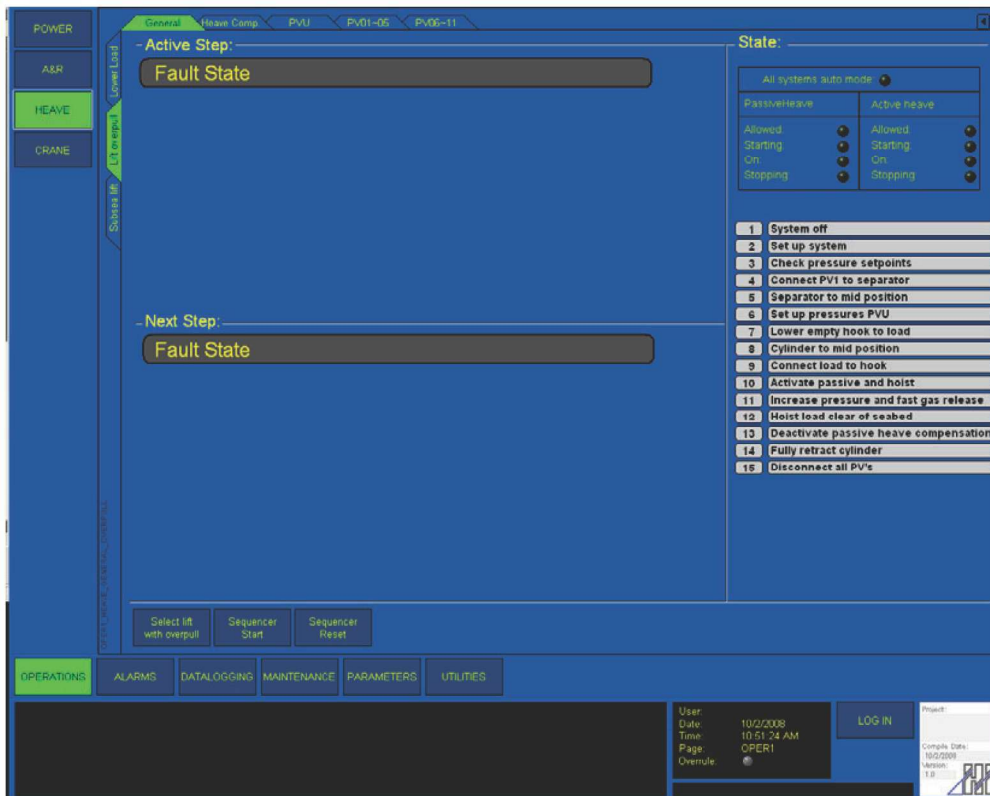


Figure 5-42: OPERATIONS > HEAVE > GENERAL > LIFT OVERPULL

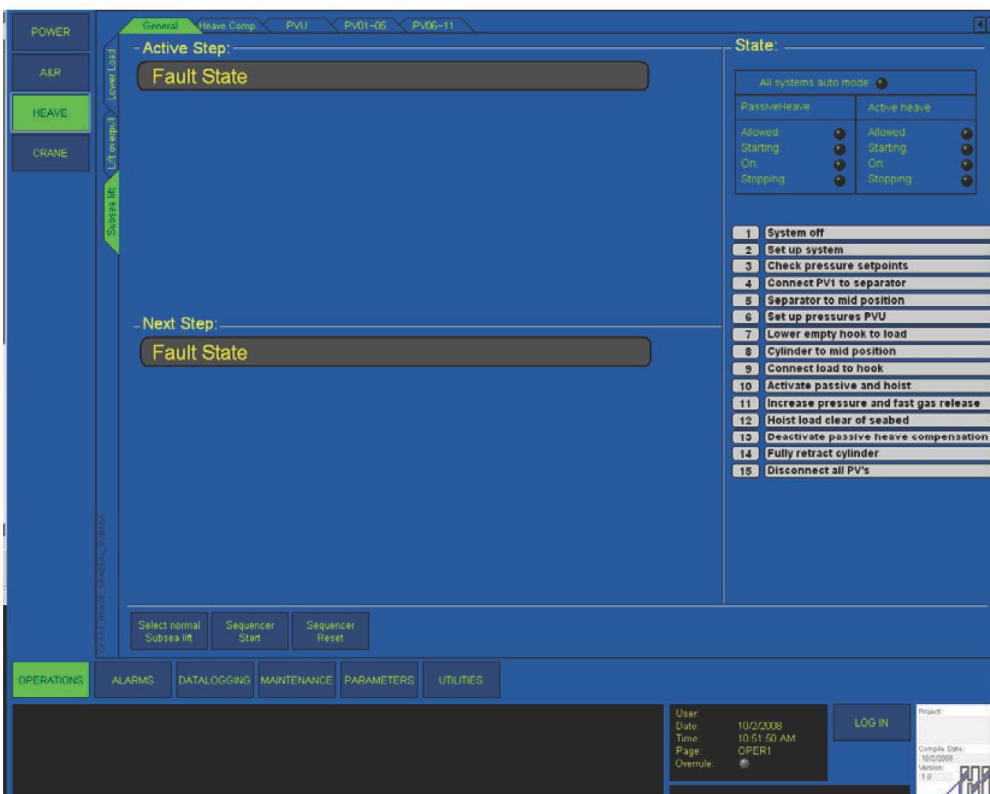


Figure 5-43: OPERATIONS > HEAVE > GENERAL > SUBSEA LIFT

5.5.8 Fast Gas Release

When an object is being lifted from the seabed it may be necessary in some cases to apply a higher line pull to this object than its submerged weight because the structure may be stuck in mud. The fast gas release function enables the operator to apply a higher static load (= higher gas pressure). As soon as the structure gets loose from the seabed the wire tension will drop. At that particular moment the operator may apply the "fast gas release" function. In fact a vessel with lower pressure is then connected to the operational vessels. The gas pressure in the operational vessels will then decrease at a high rate.

5.6 300T TRACTION WINCH

5.6.1 Operational description

The traction winch consists of an upper and a lower drum; both of them are driven by four electric motors, which in are controlled by frequency drives (make Vacon). The purpose of the traction winch is to take the load; no wire is stored on the drums of the traction winch. There are typically 5 loops on the drums at any time to provide sufficient friction. The drives are connected to the PLC via Profibus. For a full description of the communication see Appendix X: "Functional specification DCC".

As the traction winch determines the speed of the hoisting/lowering of the load, there is only speed control available from both the local control and the bridge control.

5.6.2 Control

Local control can only be activated when the winch is not moving (i.e. the brakes of the traction winch are applied).

The winch is operational if all of the following conditions are met:

- No emergency stop is actual.
- System on from SCADA. Note that the system can not be switched off in case of a brake apply or slipping brake failure!
- Movements disabled switch not active on the local control panel.
- The drives are active.
- All remote IO units are OK.
- All power supply is OK (24V control power).

Movement of the winch is only allowed if all of the following conditions are met:

- The winch is operational.
- The storage winch is in CT mode.
- No stop all movements command.

The winch can be operated in speed mode only. The pay-out length is measured on the sheave mounted on the spooling device. In normal operation the two drums operate in master/slave modus.

The movements disabled indication is lit if the drive indicates the movements disabled mode is active.

5.6.3 System Modes

5.6.3.1 Speed mode

In local control (either in normal mode or in service mode) the speed of the winch is determined by the joystick on the local control panel. The joystick setpoint is curved for accurate control at low speeds (quadratic curve) The speed setpoint is ramped by the drive.

The pay-out speed is reduced to max 30% on pre-empty drum of the storage winch. The pay-out movement (also the traction movement) is stopped on empty drum of the storage winch.

The pay-in speed is reduced to max 30 % on pre-highest position of the storage winch.

5.6.3.2 Service mode

In service mode the separate drums can be selected and controlled by the joystick.

5.6.4 Lubrication

The lubrication pump only runs if the traction winch is running. The lubrication is cyclic: lubricate time, wait time, lubricate time, etc. The lubrication cycle is always active. The lubrication pump can be started manually on SCADA (restart cycle). The wait time and the lubrication time are both set by parameters on SCADA.

If the winch stops during lubrication, the lubrication time left is finished the next time the winch starts (no extra waiting time is added).

The gearboxes of the traction winch are cooled by oil-coolers. The temperature of the gearboxes is measured and when the temperature rises above a setpoint, the coolers are switched on. The coolers are switched off when the temperature falls below another setpoint. The hysteresis prevents rapid on/off-switching of the oil-coolers.

5.6.5 Visualization

The SCADA system displays the following information for the traction winch:

- System state (drive on/off)
- DISPS OK
- Brakes lifted
- Linepull
- Drum speed
- Control location
- Active mode (speed/service)
- Messages
- Service mode selection button
- Local control request button/ Release control button

Figure 5-45 and Figure 5-44 show the OPERATIONS screens for the A&R system.

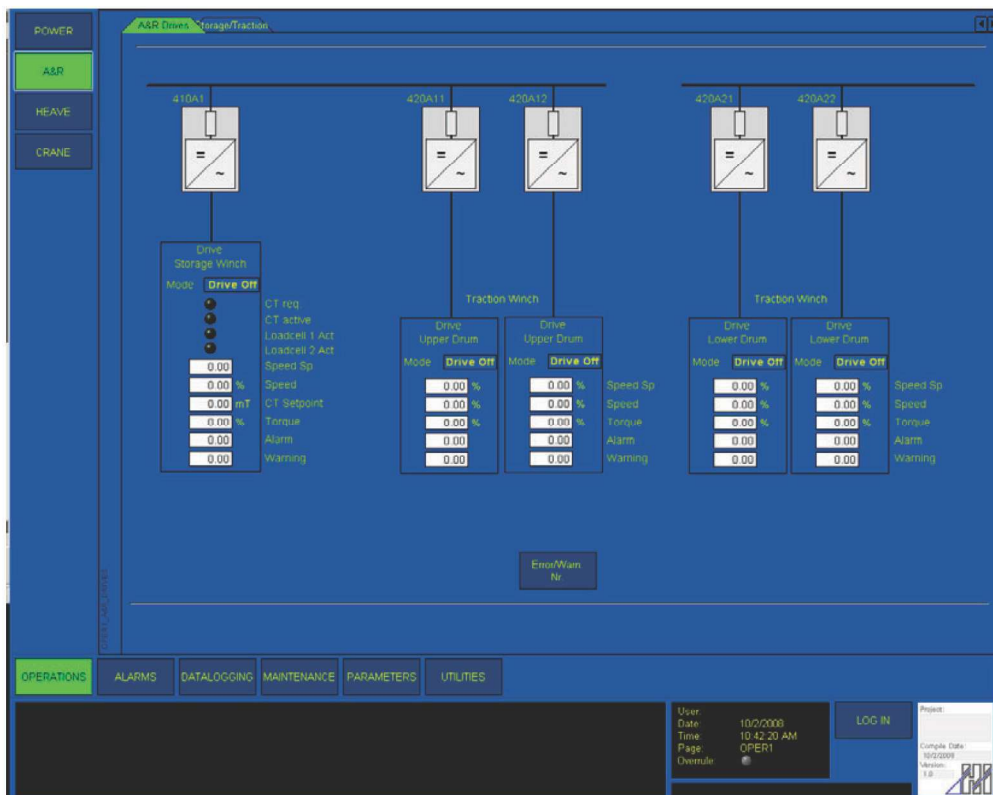


Figure 5-44: OPERATIONS > A&R > DRIVES



Figure 5-45: OPERATIONS > A&R > STORAGE / TRACTION

The PARAMETERS and MAINTENANCE screens for the A&R system are shown in Figure 5-46 until Figure 5-48.

General

- Parameters:

Control handover timeout	0.00		
Loadcell overrule reset time	0.00		
StorW pos. reduced speed limit	0.00	%	
StorW neg. reduced speed limit	0.00	%	
StorW CT setpoint	0.00	ton	
StorW Minimum to enter CT	0.00	ton	
StorW Maximum load to enter CT	0.00	ton	
StorW Max CT deviation	0.00	ton	
StorW highest position value	0.00	m	
StorW prehighest position value	0.00	m	
StorW pre-empty position value	0.00	m	
StorW empty position value	0.00	m	
StorW gearbox temp. warn level	0.00	°C	
StorW gearbox temp. alarm level	0.00	°C	
StorW lubrication start speed	0.00	%	
StorW lubrication on interval	0.00	s	
StorW lubrication off interval	0.00	s	
StorW safe working load	0.00	ton	
length measurement faultmargin	0.00	m	
StorW LengthMeasResolution	0.00		
TracW pos. spdlim. no fidweak	0.00	%	
TracW neg. spdlim. no fidweak	0.00	%	
TracW pos. reduced speed limit	0.00	%	
TracW neg. reduced speed limit	0.00	%	
TracW gearbox temp. warn level	0.00	°C	
TracW gearbox temp. alarm level	0.00	°C	
TracW lubrication start speed	0.00	%	
TracW lubrication on interval	0.00	s	
TracW lubrication off interval	0.00	s	
TracW load warning level	0.00	ton	
TracW load alarm level	0.00	ton	
TracW safe working load	0.00	ton	
TracLengthMeasResolution	0.00		
T cooling fans delayed off time	0.00	s	
TracW field weakening allowed	0.00		
TracW DISPS NoX speed	0.00		
TracW max. allowable speed diff	0.00	%	

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OPERATIONS ALARMS DATA LOGGING MAINTENANCE **PARAMETERS** UTILITIES

User: 10/2/2008 11:00:16 AM
Date: 10/2/2008
Page: PARM
Overrule:

Project:

Compile Date: 10/2/2008
Version: 1.0

Figure 5-46: PARAMETERS > A&R > GENERAL

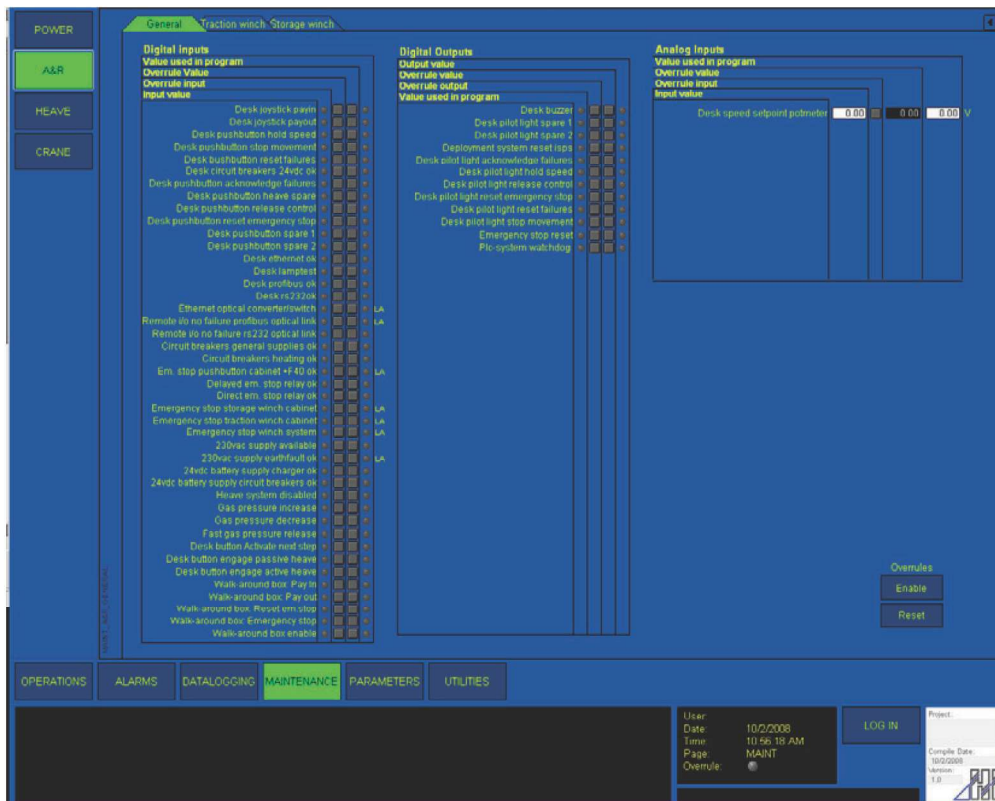


Figure 5-47: MAINTENANCE > A&R > GENERAL



Figure 5-48: MAINTENANCE > A&R > TRACTION WINCH

5.7 15T STORAGE WINCH

5.7.1 Operational description

The storage winch is used to maintain a certain tension at the traction winch to get enough friction between drums and wire for the traction winch to operate correctly. If this tension becomes too low the movement of the traction winch has to be stopped.

The storage winch is equipped with a mechanical spooling device to reduce the fleet angle and assure correct spooling of the wire. No control system is needed for the operation of the spooling device.

In normal operating mode, the winch is set to constant tension and therefore follows the speed of the traction winch. In service mode the winch is operated from the local control panel and the winch is set to speed mode.

5.7.1.1 Control

Local control can only be activated when the winch is not moving (i.e. the brakes of the traction and storage winch are applied).

The winch is operational if all of the following conditions are met:

- No emergency stop is actual.
- System on from SCADA. Note that the system cannot be switched off in case of a brake apply or slipping brake failure!
- Movements disabled switch not active on the local control panel.
- The drives are active.
- All remote IO units are OK.
- All power supply is ok (24V control power).

Movement of the storage winch is only allowed if the winch is operational. The movements disabled indication is lit if the drive indicates the movements disabled mode is active.

5.7.2 System Modes

5.7.2.1 Speed mode

With local control the winch can be operated in speed mode. The speed of the winch is determined by the joystick on the local control panel. The joystick setpoint is curved for accurate control at low speeds (quadratic curve). The speed setpoint is ramped by the drive.

The pay-out speed is reduced to max. 30% on pre-empty drum. The pay-out movement is stopped on an empty drum detection. The pay-in speed is reduced to max. 30% on pre-highest position.

5.7.2.2 Constant tension

In the bridge operator panel the storage winch can be set in CT control if hoisting and lowering is allowed. The CT setpoint is fixed at 15 mT. Constant tension control is done by the drive.

The gearboxes of the storage winch are cooled by oil coolers. The temperature of the gear-boxes is measured and when the temperature rises above a setpoint, the coolers are switched on. The coolers are switched off when the temperature falls below another setpoint. The hysteresis prevents rapid on/off-switching of the oil-coolers.

5.7.3 Visualization

The SCADA system displays the following information for the storage winch:

- System state (drive on/off)
- Brakes lifted
- Linepull
- Drum speed
- Paid out length with reset option
- Control location
- Active mode (CT/speed/service)
- Messages
- CT request button
- Service selection button
- Local control request button/ Release control button

Figure 5-49 shows the MAINTENANCE screen for the storage winch.



Figure 5-49: MAINTENANCE > A&R > STORAGE WINCH

5.8 SPOOLING DEVICE (STORAGE WINCH)

5.8.1 Operational description

The spooling device is mechanically driven by the storage winch by means of a chain. No control system is needed to guide the spooling device.

5.8.2 Visualization

No visualization of the spooling system is presented on the SCADA system.

5.9 WINCH SYSTEM AUXILIARIES

In this section, miscellaneous functions are described needed for the control of the auxiliaries of the winch system. These include the Power / DC system and the oil-coolers.

5.9.1 Transformer

The temperature of the transformers (providing main power to the winches) is monitored by PT100-elements.

Warning and trip levels (adjustable through the SCADA system) are provided to tune the system, although it is highly recommended to use the default values.

If the reading of one of the PT100-elements reaches the warning level, then a warning is shown on the SCADA system. After reaching the trip level the winches are stopped to prevent damage to the transformers.

5.9.2 Brake resistor

The brake resistor is a water-cooled resistor to dissipate the energy that is fed back to the system when a load is lowered.

To protect the resistor, both the temperature and the waterflow are monitored, with their respective warning and alarm-settings adjustable in SCADA. It is recommended not to leave these settings at their default value.

5.9.3 DC busbar

The DC-busbar of the inverter cabinet can be coupled in case there is a failure of one of the power supplies.

Typical operation is to operate the system with disconnected busbars, so that each transformer powers half of the winch system. In the event of a power failure of one of the supplies, the busbars can be coupled and the winch system can still be operated with reduced speed.

If the DC-busbars are coupled, a warning message will be shown on the SCADA system, and the maximum speed of the traction winches is decreased.

If the sensors are inconsistent, (e.g. one sensor indicates a coupled busbar, and the other one indicates a disconnected DC-system) then a warning message is shown on the SCADA system and the maximum speed of the traction winches is decreased.

5.9.4 Walk-around box

A control box with flexible cable will be provided to operate the winch on deck.

On the bridge, control can be assigned to the WAB by means of a switch. Switchover of control between the bridge and the WAB is unconditional.

The following controls are available on the WAB:

- Emergency stop
- Emergency stop reset
- Pay-in

- Pay out

There is no visual cue that the WAB is operational; this has to be communicated between the bridge and the WAB-operator by other means.

If the WAB is not activated, then the buttons are inoperational (except for the emergency stop pushbutton).

If the WAB is operational, then the pushbuttons “pay-in” and “pay-out” will override the joystick controller setpoint of the bridge by a constant value (this value can be changed by a parameter).

If the winch is operational, and could in principle be operated from the bridge, then operating the winch from the WAB will cause the system to slowly pay-out/haul in the wire at a fixed speed.