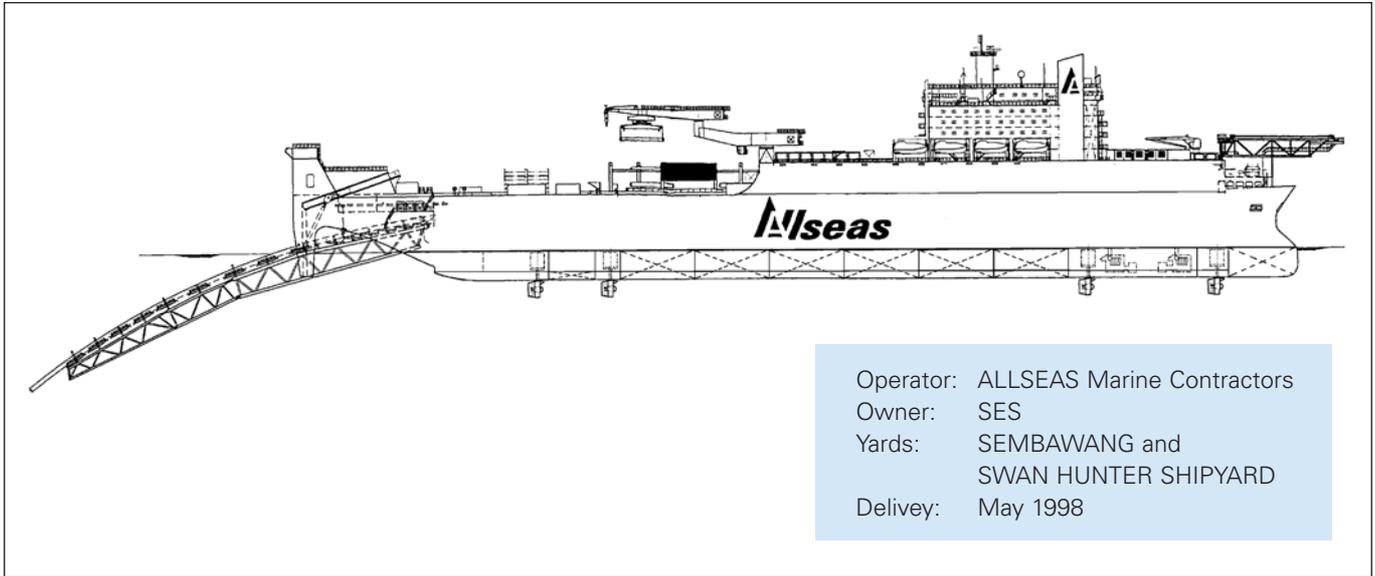


Pipelaying Vessel „SOLITAIRE“



Electrical Propulsion System
10 kV Supply and Distribution System

"SOLITAIRE" - the World's Largest Pipelaying Vessel



Operator: ALLSEAS Marine Contractors
 Owner: SES
 Yards: SEMBAWANG and SWAN HUNTER SHIPYARD
 Delivery: May 1998

Main data:		Pipelaying rate	6 km/day
Length incl. stinger	368 m	Max. pipe diameter	60 inches
Width	40.6 m	Cruising speed	12 kn
Draught	14.5 m	Generator power	48 MW
Displacement	76909 t	Thruster drives cont. load	34.4 MW
Accommodation capacity	420 pers.	Thruster drives peak load	44 MW

SAM Electronics had the system responsibility for: diesel-electric propulsion system, 10 kV power generation, 10 kV switchgear, 10 kV transformers, navigation, communication, entertainment and C.C.T.V. system.

- Propulsion and power components delivered by SAM Electronics:
- 8 diesel-electric azimuth thruster drives incl.:
 - 8 synchronous motors 4.3 MW, 465 rpm, six-phase (peak load 5.5 MW, 520 rpm)
 - 8 synchro-converters incl. control and monitoring system, 24/12-pulse
 - 16 cast resin transformers 3 MVA, 10 kV / 790 V
 - 8 diesel generators 8 MVA, 10 kV, 60 Hz, 514 rpm
 - 2 switchboards 10 kV with 36 panels for high voltage distribution
 - 12 cast resin transformers for low voltage supply 2.0 - 3.5 MVA

Pipelaying Motor Vessel

The „Solitaire“, the world’s largest pipelaying vessel, has been in service since spring 1998. The offshore company ALLSEAS has the ambitious aim of laying the largest pipe diameters at twice the speed of the best competing vessels. With its displacement of 76909 tons, its dynamic positioning system according to NMD Class 3, extended firing line and 108 m stinger, the vessel has been designed to lay pipes with a diameter of up to 60 inches at a rate of up to 6 km per day at water depths exceeding those reached by moored barges.

The „Solitaire“ is equipped with 8 azimuth thrusters having fixed-pitch propellers for the dynamic positioning and propelling of the vessel. The vessel’s large hull and dynamic positioning permit work to be performed at unlimited water depths and under adverse weather conditions, since tug boats for mooring are not required. With the integrated propulsion power of 34.400 kW, the vessel achieves a transit speed of 12 knots.

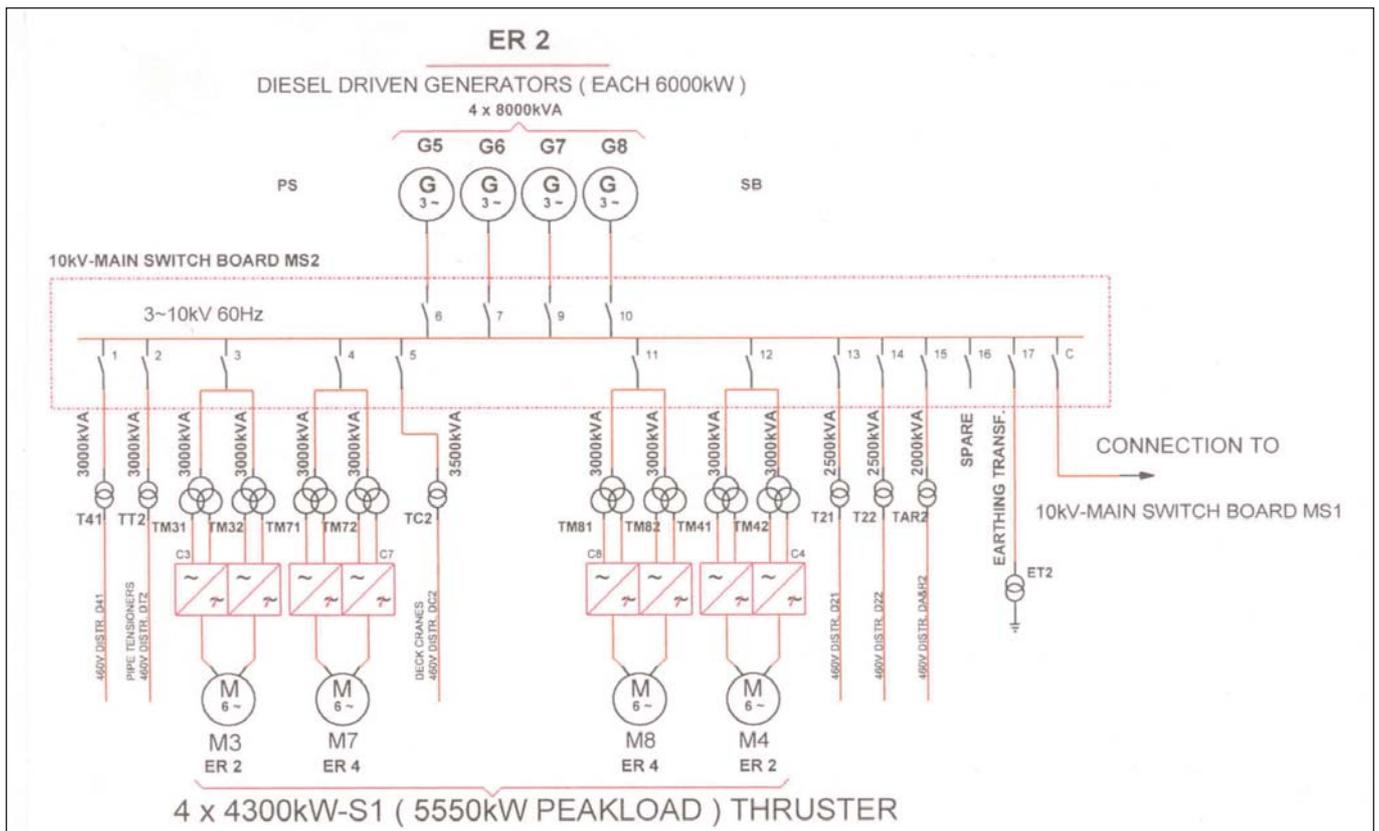


The Layout of the Electrical Power Plant

Power generation and distribution according to the power station principle are performed by 8 diesel generators via linked busbars. The engine rooms are divided into 4 separate watertight compartments (2 forward and 2 aft).

Each 10 kV busbar supplies 2 aft and 2 forward thrusters and six 460 V substations. An earthing transformer with secondary resistor in each 10 kV system limits the earth fault current at the 10 kV busbar to 10 A and 20 A with

open and closed bus tie breaker, respectively. The earthing system is designed for continuous operation with a single earth fault.



Generator data

- Rating 8000 kVA, 6000 kW at 514 rpm
- 10 kV, 60 Hz
- Stator with vacuum-impregnated windings (VPI)
- Salient-pole rotor
- Brushless excitation with monitored rotating diodes and protective wiring
- 2 sleeve bearings with hydrostatic pumps for regular slow turning of the diesel engines
- Enclosure IP54



Diesel generators 1-4

The Thruster Propulsion System

The „Solitaire“ is driven and positioned by 8 variable-speed, 360° rotatable azimuth thrusters with fixed-pitch propellers. The synchronous motors with brushless excitation are fed by synchro-converters.

Advantages of variable-speed thruster drives

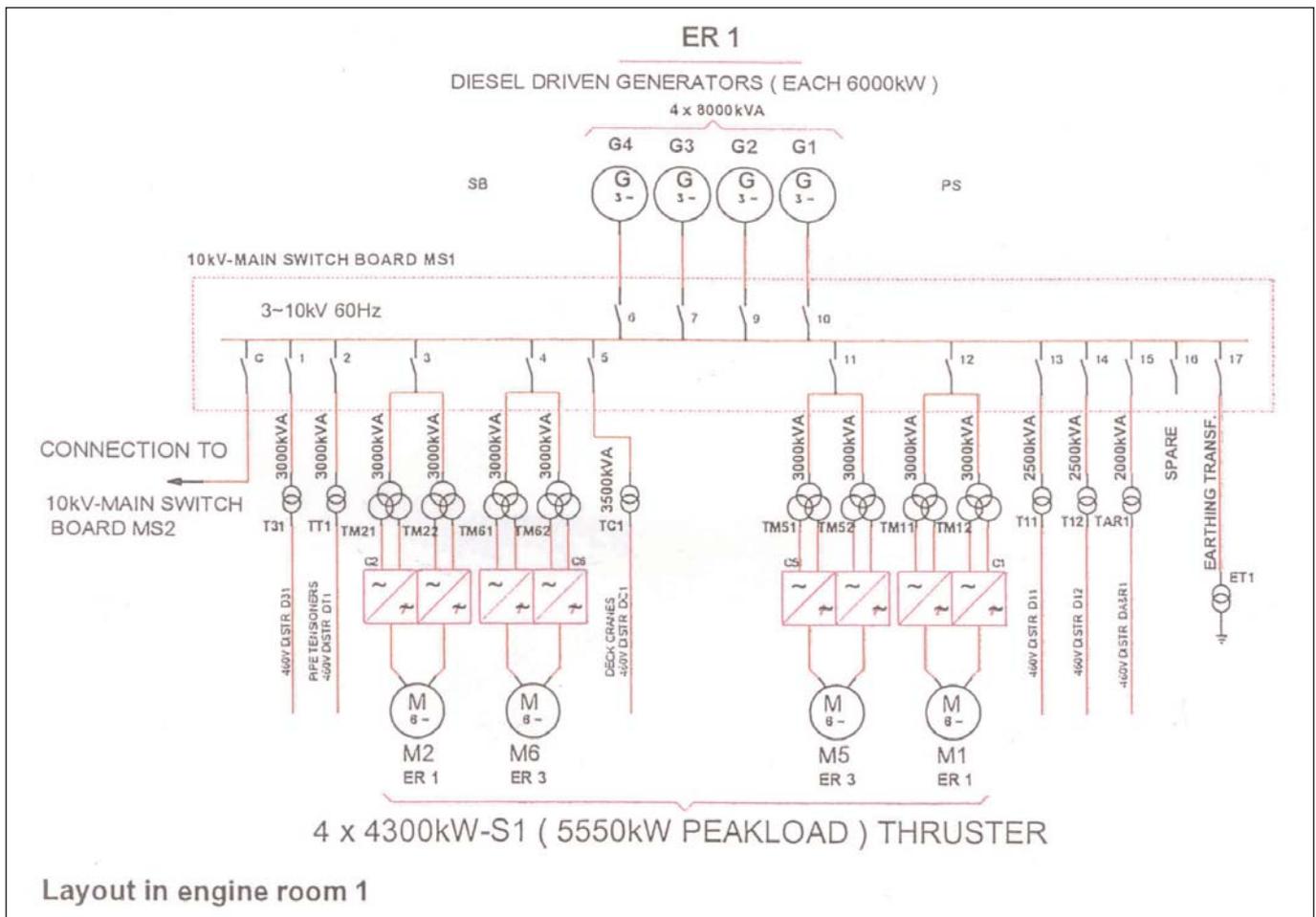
The variable-speed drives offer many advantages as compared to thruster drives with controllable-pitch propellers:

- Variable-speed drives reduce operating costs since only the power for the thrust actually required is taken from the network. Under no-load conditions, less than 5% of the rated

current (including excitation) is required. Asynchronous motors require 20 to 35% of the rated current under no-load conditions.

- The losses of a CP propeller at low load amount to approximately 25% of the propeller design power. The losses of the synchro-converter drive in the low power range amount to approx. 1% of the rated power.
- High efficiency over the entire speed range. Even at rated speed, the efficiency of a CP propeller is lower than that of a fixed-pitch propeller due to the larger diameter of the propeller hub.

- In the partial load range, FP propellers produce less noise and cavitation than CP propellers.
- The current during acceleration of the drive to rated speed is similar to the rated current. Therefore, severe voltage drops in the supply network - as in the case of uncontrolled drives - do not occur.
- Stable operation of the vessel's network due to immediate power limitation on sudden loss of a generator.



The Eight Propulsion Motors

The synchronous motors are designed for variable-speed drives with brushless excitation. The stator winding comprises two star-connected 3-phase systems of 1300 V each which are electrically shifted by 30° (6-phase motor). The motor shafts are arranged vertically, and the motors are equipped with 3 preloaded ball bearings each for 100000 operating hours. The motors are of the enclosure type IP55, and they are cooled by two external fans in a closed circuit via an air/water heat exchanger installed laterally. In the case of failure of the vessel's cooling water system, continued operation of the motors with approx. 80% of rated power is possible by opening up emergency flaps and cooling with ambient air. The asynchronous exciter with its monitoring devices ensures maintenance-free operation.

Propulsion motor data:

- Rating 4300 kW at 465 rpm (5550 kW peak at 520 rpm)
- Stator with 2 separate winding systems
- Non-salient pole rotor with damping winding
- Brushless excitation with rotating diodes and thyristor protection device
- IM V1 design with vertical shaft arrangement
- 3 preloaded ball bearings with an operating time of 100000 hours
- Enclosure IP55



Thruster motor

The Eight Synchro-Converters

The synchro-converter system with its proven and simple converter configuration has been in use in various applications aboard various vessels for many years. The converters of the „Solitaire“ with a rated power of 5500 kW, are constructed with 24-pulse design for low network distortion. The low total harmonic distortion factor (THD) in the 460 V distributions is achieved without the use of filters.

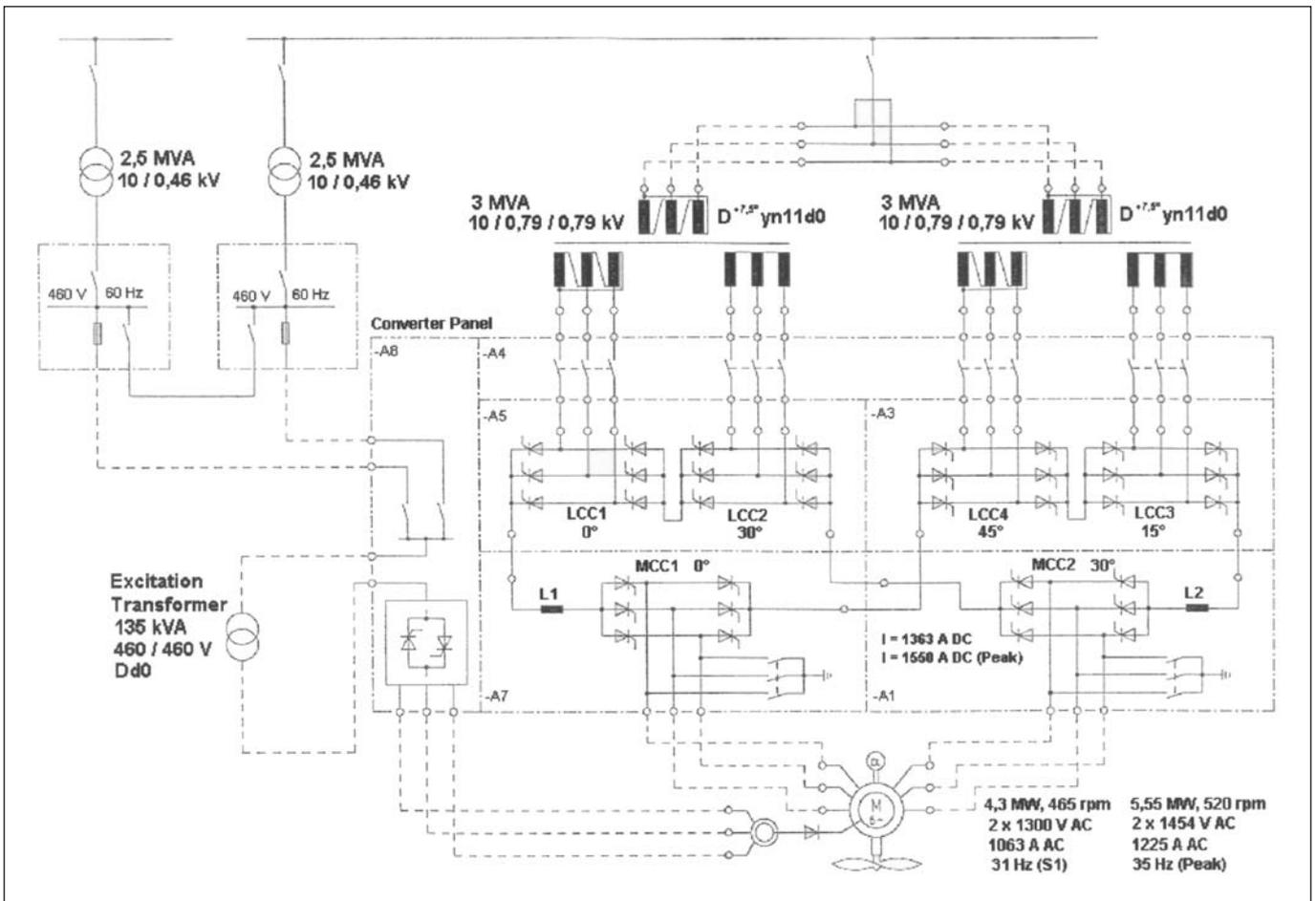
Characteristics of the 24/12-Pulse Synchro-Converter System

The main components of the converter are the line-commutated converter (LCC), the smoothing choke for the DC link and the motor-commutated converter (MCC). The LCC is a fully controlled

3-phase thyristor bridge on the network side. The LCC is operated as a controlled rectifier and is used for setting the speed of the motor via the intermediate DC current and voltage. The MCC is used for converting the DC link voltage into AC of the required voltage and frequency.

The MCC consists of a fully controlled thyristor bridge and is commutated by the motor voltage. The drive system can be compared to an externally excited DC drive with its rotor having been repositioned into the stator and with its commutator being formed by the inverter - the MCC. The pulses are formed automatically by detecting the zero crossings of the motor voltage. For reduction of harmonics and torque

pulsations in the air gap, the six-phase synchronous machine is fed in 12-pulse mode by 2 inverters which are operated with a phase shift of 30°. The four line commutated converters are fed by 2 double deck transformers with a phase shift winding of 7.5° on the high voltage side. The connection with clockwise and counterclockwise rotary field produces a phase shift of 15°. For the 24-pulse operation, special symmetrization of the current in the DC link is unnecessary due to series connection of all thyristor bridges (Punga connection), so that only one common current flows in the converter. Due to the exact 24-pulse system, a THD of 6% at rated data is achieved without any additional filtering.



Data of the Synchroconverter

All functions of drive control, process regulation, drive regulation, set value processing and monitoring are performed by the multiprocessor system Logidyn D. The control functions of the MCC and LCC run on the processor unit CCU096 and the functions of the superordinated control and monitoring tasks run on the control unit MCU032 in multitasking mode.

The control and monitoring tasks are freely programmable on the CAD system „LogiCAD“ on a personal computer. The logical structures are programmed and documented graphically. All currently existing settings and values of the digital controllers can be shown on a personal computer; telediagnosics via satellite is possible with the use of an additional PC and supplementary software.



Synchroconverter

Data of the synchroconverter:

- 4 controlled rectifiers for 24-pulse network operation
- 2 inverter bridges for 12-pulse motor operation
- 2 integrated DC link chokes
- Series connected (Punga connection) with common circuit
- Closed circuit air cooling with 4 integrated air/water heat exchangers
- Control and regulation system with internal diagnostic system, which detects malfunctions and signals them to the automatic vessel management system (AVM) via a serial link.

The Transformers

Cast-resin transformers with coils of high electrical, thermal and dynamic strength were chosen due to their many advantages:

- **Moisture proof:** The complete embedding of the windings in epoxy resin prevents moisture from penetrating into the windings and causing thermal breakdowns. This insulation offers maximum protection against an aggressive salty and moist environment.
- **Immediate switch-on:** Owing to the insulation materials used, the transformers can be immediately switched on without predrying, even after extended periods of idleness.
- **Impulse strength:** In contrast to conventional dry-type transformers, cast-resin transformers are resistant to impulse voltage according to IEC76 and VDE 0111.

- **Short-circuit strength:** The dynamic short-circuit strength is considerably higher than for conventional dry-type transformers.
- **Free from partial discharges:** No partial discharges of more than 20 pC in the windings, thus an increased life of the transformers.
- **Resistant against temperature fluctuations:** The glass-fibre reinforced epoxy-resin laminates are resistant even against extreme temperature fluctuations.
- **High overload capacity:** Owing to the high heating time constants and the high insulation material classes, cast-resin transformers can be overloaded considerably longer than any other transformer.
- **Flameproof:** The insulation materials used are flameproof against electrical arcs and are self-extinguishing (more than 90% of the coil materials are glass and copper).

Propulsion transformer data:

- Power 3000 kVA (peak load 3400 kVA)
- 2 secondary windings, vector group D+7.5° y11d0
- Phase shift 15° el. between the 4 associated secondary systems for 24-pulse operation
- Secondary voltage 790 V
- Cast resin transformers
- Enclosure IP23, natural air cooling

Supply transformer data:

- Power 2000 - 3500 kVA
- Vector groups Dyn11 and Dd0
- Secondary voltage 460 V
- Cast resin transformers
- Enclosure IP23, natural air cooling

Propulsion transformer



The 10 kV Medium Voltage Switchboard

The center of the 10kV energy and distribution system consists of the two main switchboards MS1 and MS2, which are equipped with vacuum circuit breakers and are normally operated together.

The generator panels and the coupling breaker panels are equipped with the microprocessor controlled Generator Management Module GMM10. The GMM10's monitor, protect, control and synchronize both the generators and the busbar. Each transformer panel is equipped with a Transformer Protection Module TPM10. The GMM10 and TPM10 communicate via an internal bus system. Differential protection for all generators and transformers is included. Any malfunction is indicated by an internal diagnostic system, which is connected by an external data bus to the automation system of the ship. The ship's mains is controlled by the integrated Power Management System:

- 8 generator panels for generators 8 MVA
- 8 panels, each with 2 transformers for thruster drive 6 MVA (6.8 MVA)
- 12 transformer panels for 460 V distributions 2.0-3.5 MVA
- 2 panels for earthing-transformers
- 2 spare panels
- 2 synchronisation panels
- 2 panels for coupling-breakers

Characteristic Features of the Switchboard Panels of Type WBB

- Air insulated switchboard panels, metal-enclosed, metal-clad with single busbar
- Vacuum circuit breaker mounted on plug-in unit
- Cable connection compartment accessible through separate door
- High operating safety due to completely clad busbar compartment even with the breaker in test position

- Protection, monitoring and control by the microprocessor-controlled protection system GMM10 / TPM10
- Check of circuit breakers and copper busbars via comparative resistance measurement

Definition and Insulation Coordination
The complete high voltage system of the „Solitaire“ was simulated on a computer. In this process, the main

data for the earthing concept and the insulation coordination were investigated in order to confirm possible voltage peaks which may result from switching or faults of machines or cables.

One result of the simulation was the mounting of surge voltage arresters in critical circuits for protection of machines and transformers.



Switchboard: 10 kV High Voltage

Equipment delivered by SAM Electronics for the „SOLITAIRE“

- 8 azimuth thruster drives:
 - 8 synchronous motors
4.3 MW 465 rpm
(5.5 MW 520 rpm peak load)
 - 8 synchro-converters 24/12-pulse
incl. control and monitoring system
 - 16 cast resin transformers
 - 8 excitation transformers
- 8 diesel generators 8 MVA, 10 kV, 60 Hz, 514 rpm
- High voltage switchboard 10 kV
 - 36 panels
 - Protection system
 - Earthing transformers and resistors
 - UPS
- 12 cast resin transformers for low voltage supply
- 4 air chokes for short circuit damping in low voltage switchboards
- 16 inch radar
- Doppler speed log
- Echo sounder
- D-GPS
- Decca
- Loran-C
- Radio direction finder
- Rate-of-return indicator
- Radar beacon
- Weatherfax receiver
- Weather satellite system (NCAA)
- Meteo equipment
- GMDSS radio station
- Radio station for public purposes
- VHF network for internal communication
- Helicopter communication
- Automatic telephone exchange
- Public address and general alarm network
- UHF trunking system
- Talk back system
- Sound powered telephone network
- Audio entertainment (radio broadcast, C.D., cassette)
- Video entertainment (satellite TV receiver, off air broadcast, VHS)
- C.C.T.V. security and observation system

