ELECTRIC POWER AND PROPULSION

THE NEWBUILDING LPDs FOR THE ROYAL NAVY

BY

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ABSTRACT

The article reviews the propulsion plant selected for the new Landing Platform Docks now building at VSEL, Barrow-in-Furness, and the reasons for it. It considers the Through Life Cost, the use of Commercial Off The Shelf equipment, system configuration and how these have met the Royal Navy's requirements.

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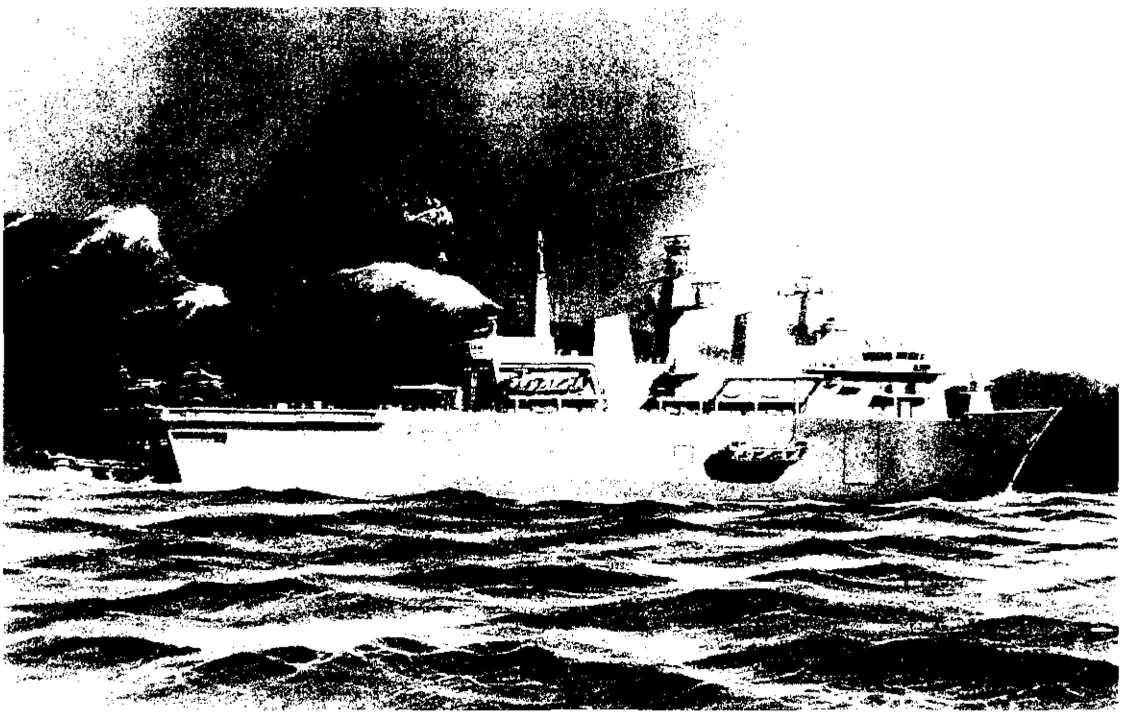

FIG.1 - ARTISTS IMPRESSION OF A LPD

Introduction

The assault ships HMS *Albion* and *Bulwark*, otherwise known as Landing Platform Docks (LPDs), will be the Royal Navy's first fully electrically propelled front line ships and will replace the now ageing *Intrepid* and *Fearless*. These vessels will play on important part in the new Rapid Response Force formed in cognisance of the significant changes in the Navy's role following the end of the Cold War. The subsequent placing of an order for two diesel electric Auxiliary Oilers (AO) confirmed the Ministry of Defence's commitment to electric propulsion.

The decision to select diesel electric propulsion was made after work on the design for the hull and machinery space layout for a mechanical drive installation had begun. The most cost effective way of proceeding was to make as little change to the vessel as possible—thus LPDs designed from the outset for direct mechanical drive now have a diesel electric plant installed. It has proved to be a dimensional constraint in places but through design flexibility, the new installation has been achieved.

WHY WAS ELECTRIC PROPULSION CHOSEN FOR LPD?

Background

When selecting the power and propulsion system for any vessel it is essential to consider the vessel's operating profile. What is the vessel for and how is it intended to be used?

The function of LPDs is to transport, sustain, and disembark a military force complete with equipment, artillery, vehicles and stores into any theatre. The LPDs operate a dock at the stern which, by ballasting, allows assault and landing craft to embark and disembark men and vehicles under controlled conditions. The vessels can also operate helicopters. In addition to their military role, LPDs are able to perform a wide range of peacekeeping and civil operations.

Propulsion plant layout

The original direct mechanical drive proposal is shown in (FIG.2), two propeller shafts, each powered via a double input gearbox normally driven by a propulsion diesel engine. For prolonged periods at speeds below 6 knots, a loiter drive facility is provided by way of a variable speed motor coupled to the gearbox.

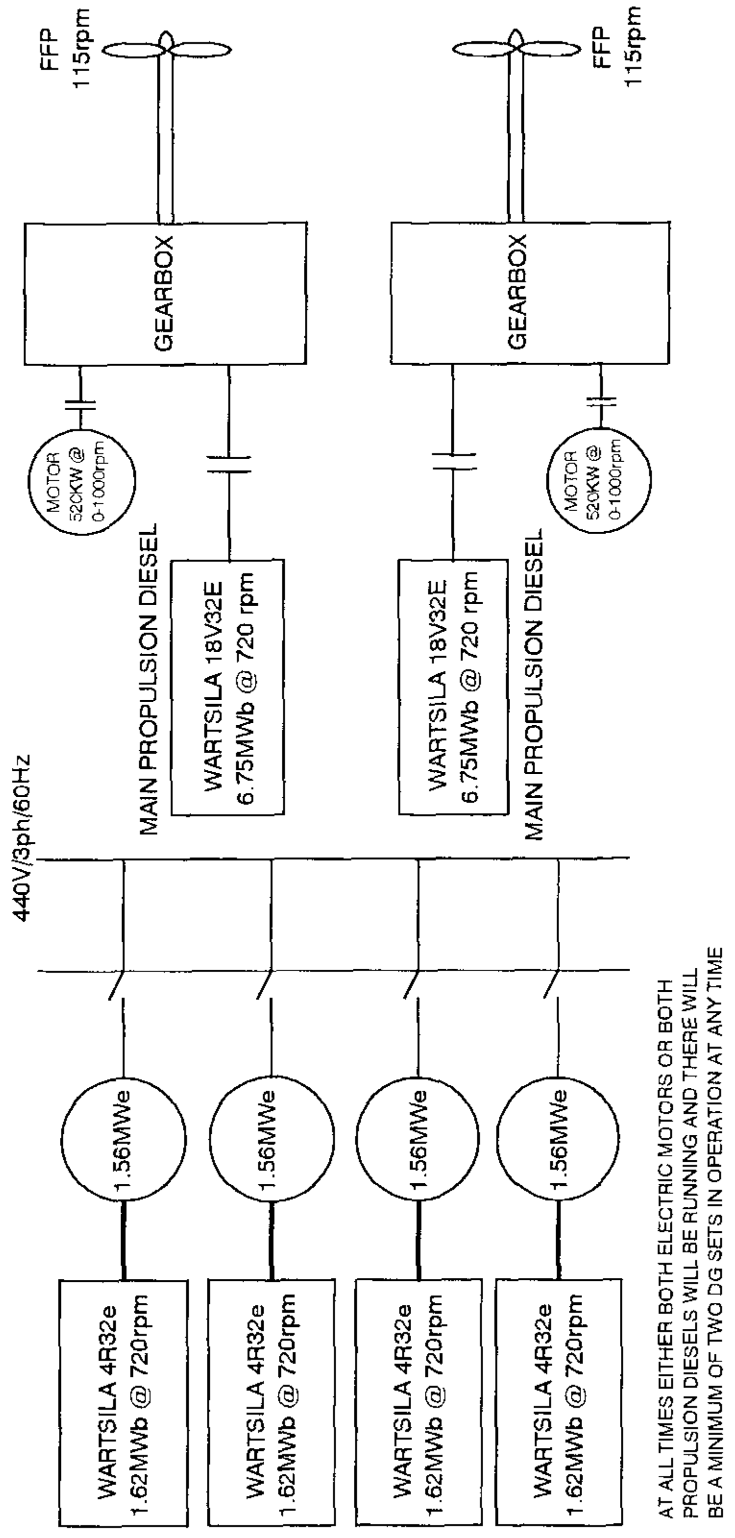

FIG.2 - LPD DIESEL MECHANICAL PLANT CONFIGURATION

(Fig.3) shows the alternative diesel electric configuration, the two shafts are driven by a variable speed AC motor fed via a synchrodrive. Power is generated by four diesel generator sets at 6.6kV and distributed via step down transformers to the ship's service network.

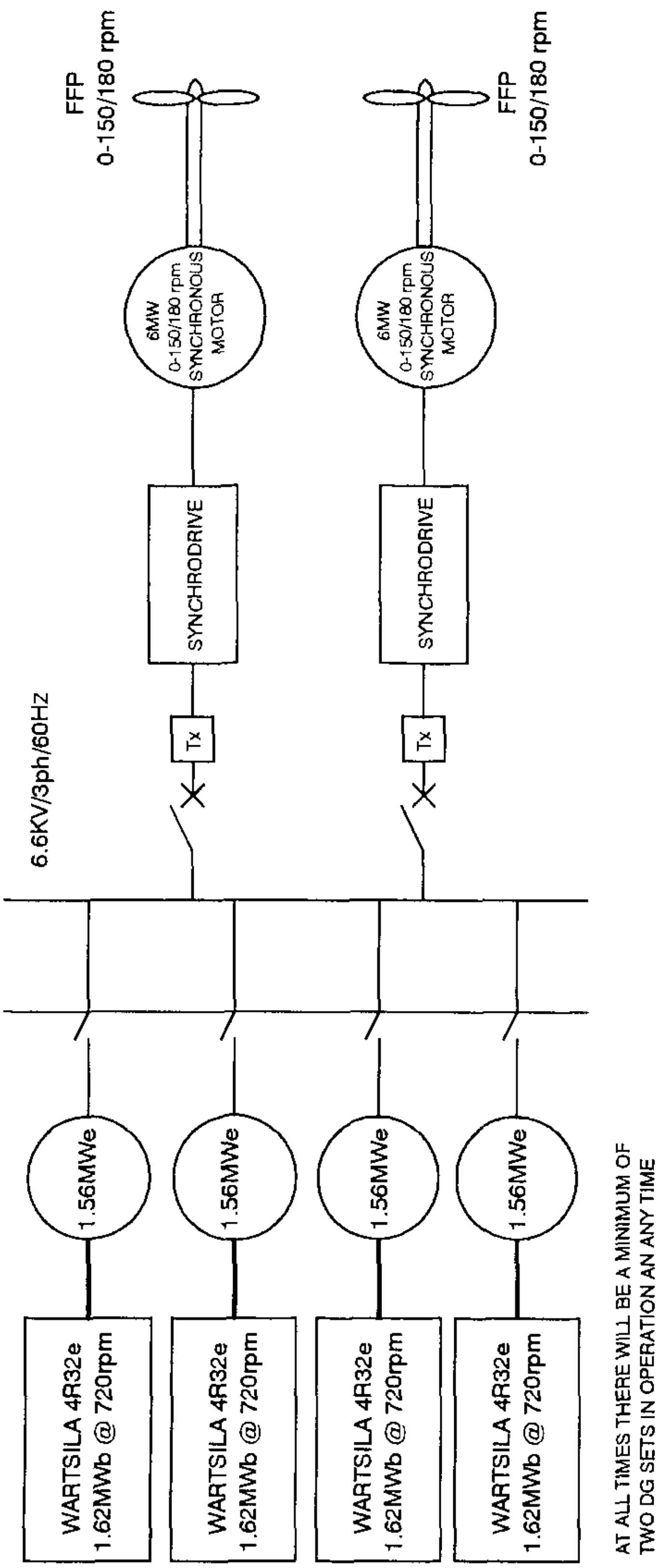

Fig.3 - LPD Diesel electrical plant configuration

Operating profile

Based on the typical operating profile of an LPD, (FIG.4) compares engine running hours for a given speed for a direct drive mechanical solution with those of a diesel electric alternative.

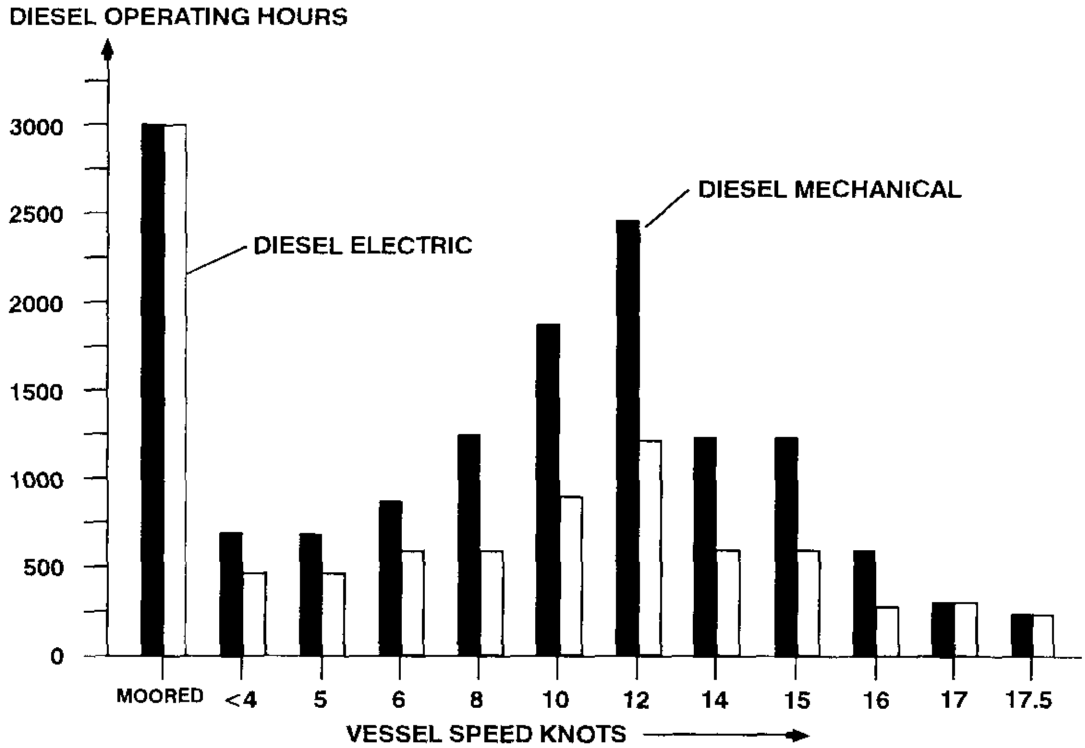

FIG.4 - DIESEL OPERATING HOURS/YEAR

For clarity, Table 1 summarizes the percentage of operating time spent at particular Maximum Continuous Ratings (MCRs) in the mechanical drive vessel.

TABLE 1—*Diesel Engines MCR*

Vessel Speed (knots)	Propulsion Engine Loading (%)	Annual Operating Time (%)	≤ 30% MCR (time)	≤ 85% MCR (time)	≥ 85% MCR (time)	Diesel Electric DG Set Loadings (%)
4	21	7.5				44
5	26	7.5	25%			46
6	31	10				50
8	41	10				59
10	51	15				72
12	62	20		70%		86
14	72	10				73
15	77	10				81
16	82	5				89
17	87	3			5%	85
17.5	90	2				90

It becomes clear that for approximately 95% of the vessel's operating time, the propulsion engines are running at less than their optimum MCR. Some mitigation is provided by the inclusion of loiter motors which would operate in place of the diesel engines at speeds below 6 knots but this would only apply where a protracted period of loitering was to occur (i.e. not during manoeuvring where the diesel engines would be kept idling). This would slightly improve the overall position to give a total of around 90% of operating time spent below optimum MCR.

Such operation is not preferred for a diesel engine—particularly as this low power operating period may be extensive.

Modern diesel engines are designed to produce their optimum performance around 85% MCR. At this rating they achieve best fuel economy and when this loading is maintained, there are lower maintenance and overhaul requirements. Operating at powers below this results in less than optimum fuel consumption. At powers below 25% MCR all the undesirable effects of poor combustion are present:

- Carbon build up on valves, rings and turbochargers
- Increased wear and tear on the running gear
- Poor fuel consumption
- Black smoke.

Whereas in a mechanical direct drive vessel it is necessary to run propulsion engines at the powers dictated by the vessel's operational requirements and accept the consequences, diesel electric propulsion presents a benefit. Optimum MCR can be maintained over a significantly wider range of conditions. The inclusion of electric motors to provide a loiter drive facility offers some mitigation in the mechanical drive system.

How wide a range of operational conditions that can effectively be covered by a particular fit is the subject of detailed investigation which has to be carried out on a case by case basis. It is crucial that the vessel's operating profile is fully understood e.g. percentage time in transit, sprint, loitering, winter, summer, harbour etc., which is then mapped against available diesel engine ratings to maximize the number of engine operating hours spent at, or close to, the engines MCR. This also allows the maximum time between engine overhauls thereby reducing maintenance costs.

This is the key to reducing vessel Through Life Cost (TLC).

Diesel Electric TLC benefits over 26 years

(FIG.5) compares cumulative engine operating hours together with associated maintenance hours for both mechanical and diesel electric systems over the vessel life of 26 years. The reduction in maintenance hours, while less pronounced is still significant in percentage terms.

The decision to go diesel electric on LPDs was taken after extensive research and studies had been carried out by the MoD and independently by industry. ALSTOM Drives and Controls was commissioned by the MoD in 1995 to investigate TLC implications of various mechanical and electric drive systems for a twin shafted AO. The results of these studies helped confirm the MoD's own estimations of the benefits of diesel electric propulsion for vessels with typical naval operational profiles.

The studies for the AO were based on standard engines and the LPD was originally contracted on this basis. But the MoD, keen to extract the maximum benefits of the latest proven engine technology advances, particularly with respect to reducing engine emissions, changed to Low NOx engines at an early stage in the contract. This gives a further improvement of the TLC with a reduction in fuel consumption, making the vessel compliant with the forthcoming IMO legislation and is therefore expected to avoid the need for Selective Catalytic Reduction (SCR) devices at a later date, saving costs and space.

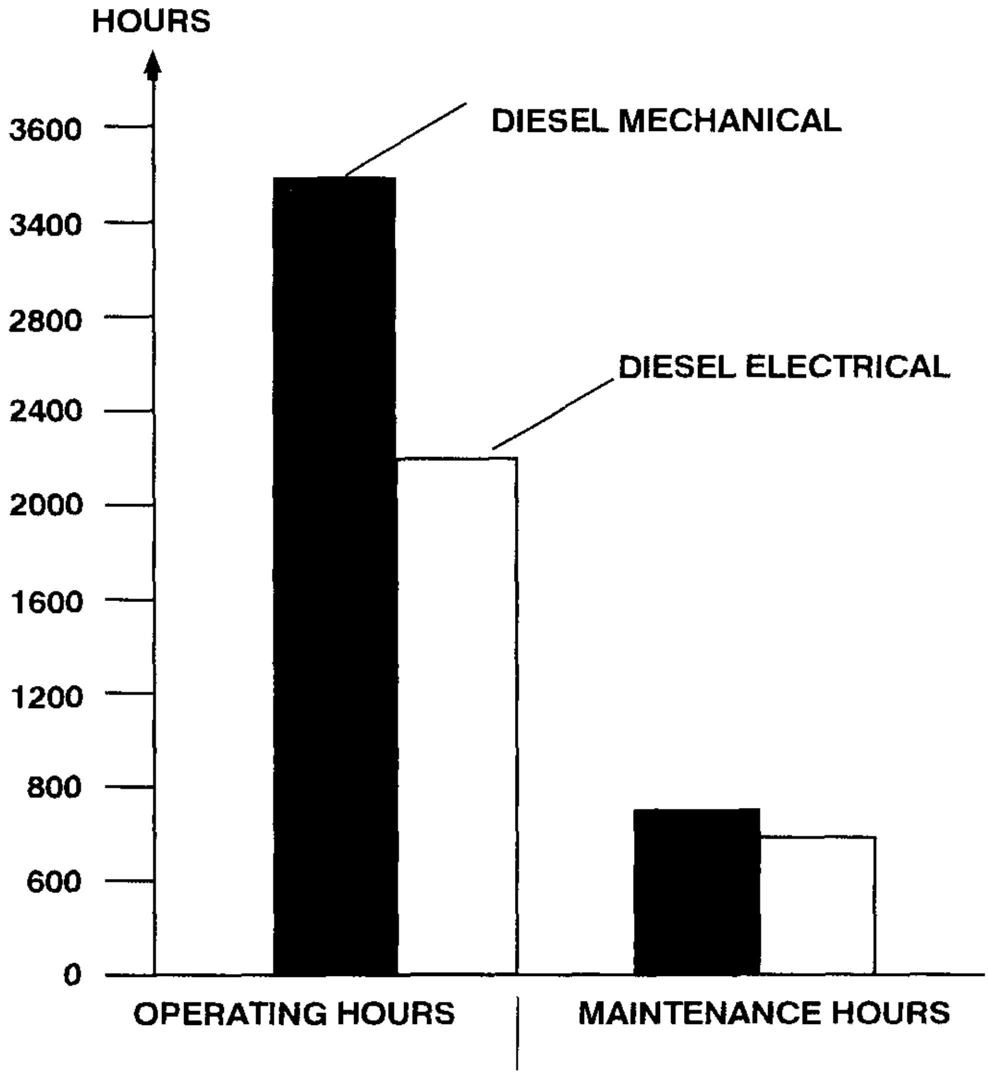

FIG.5 - OPERATION AND MAINTENANCE HOURS OVER 26 YEARS

Diesel Electric and Commercial Off The Shelf (COTS) equipment

The operational and technical benefits were better understood by the MoD as diesel electric propulsion has been used in commercial vessels over the last 10 years with increasing frequency, particularly in the offshore and cruise line market, and there are examples earlier than this. Electric propulsion is not new to the Royal Navy either, various electric propulsion systems have been in operation for some time, such as in conventional submarines, the HECLA class, RFA *Diligence*, HMS *Challenger*, RMAS *Newton* and the Type 23 frigates.

The benefits of diesel electric propulsion can be summarized as follows:

- Greater vessel operating flexibility.
- High system redundancy.
- Increased vessel availability.
- High prime mover operating efficiency.

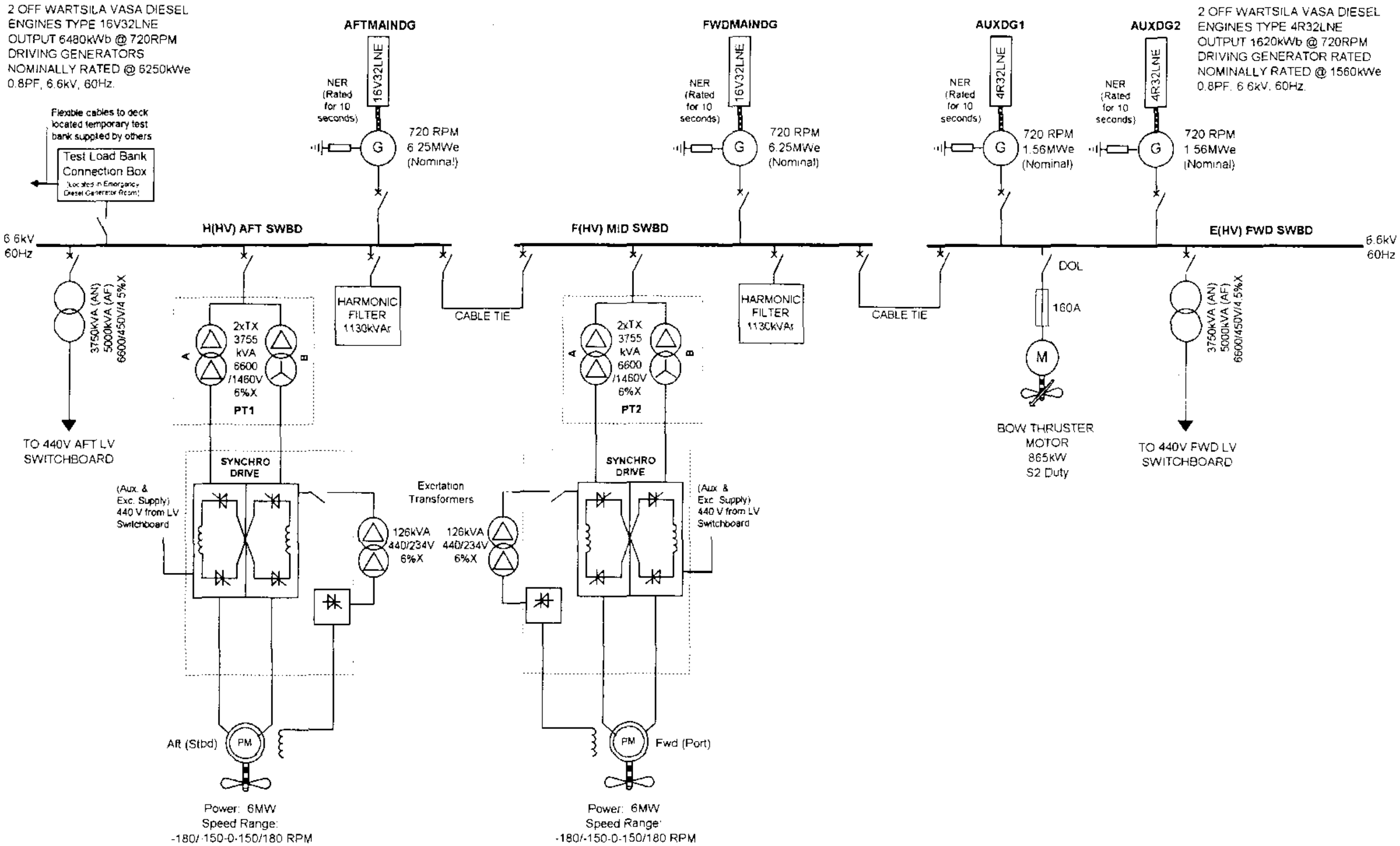

FIG.6 - SINGLE LINE DIAGRAM OF THE LPD POWER SYSTEM

- Reduced maintenance requirements.
- Phased prime mover maintenance.
- Major maintenance with vessel in service.
- Prime mover spares compatibility.
- Reduced emission levels.
- Installation flexibility.

The costs of developing fully hardened equipment for LPDs were considered prohibitive and the MoD was fully supportive of the use of COTS equipment to reduce platform costs. To minimize technical risk, all the proposed equipment was investigated for proven reliability and maintainability in both industrial and offshore marine applications.

LPD technical solution

With the decisions having been made for the LPD vessels to have full electric propulsion for their two propeller shafts, ALSTOM finalized its solution using its well proven synchroconverter load commuted inverter drives. The final ship's power system is shown in (FIG.6).

Generation and high voltage

The generation and distribution plant for the vessel was chosen at 6.6kV 60Hz, to make both the cabling and the drive input voltage practical for the power levels involved, and to enable the vessels to be fitted with COTS equipment. Although the marine and offshore industry is now well used to such voltages, this was new territory for a Royal Navy vessel, more used to voltages below 1kV, both AC and DC.

There are four diesel generators on the vessel, two main units each rated at 6.26MW and two auxiliary units rated at 1.56MW, providing a total generation capacity of 15.64kW. All of the engines are supplied by Wartsila, with all of the generators manufactured by ALSTOM Electrical Machines in Rugby.

The vessel layout has been designed to provide improved survivability and system redundancy. These considerations resulted in the HV system being divided into fwd, mid and aft sections, with the mid and aft each having one main generator, propulsion drive and harmonic filter. The fwd switchboard has two auxiliary generators, and the bow thruster motor.

One of each of the two large ship services transformers is connected to the aft and fwd switchboards to provide some distance both electrically and physically for the essential services, thereby decreasing vulnerability. Normal operation is with the interconnecting cable ties closed, but each of the boards can be automatically configured in 'Island' mode should the cable ties, or other switchboards be lost.

Propulsion

The two main propulsion shafts are identically rated with each one delivering 6000kW at a maximum speed of 180RPM. The shaft lengths are, however, different to satisfy machinery space redundancy requirements.

The motor/drive arrangement has a field weakening region from 150 to 180 RPM which allows full power to be developed with compensation for any hull fouling.

Each independent shaft is supplied by one of ALSTOM Drives & Controls' S2000 synchroconverter systems. Each synchroconverter includes 12 pulse supply and 12 pulse machine converters with a DC link connecting the bridges in a 'figure of 8' arrangement (FIG.7)

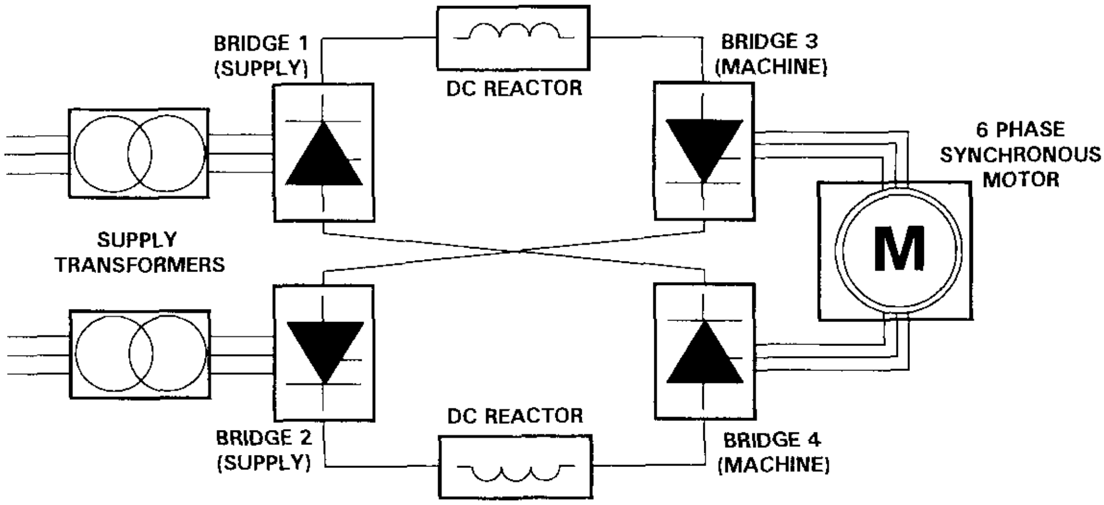

FIG.7 - SYNCHRODRIVE POWER CIRCUIT USED IN THIS APPLICATION

This arrangement has several benefits, notably a reduction of harmonic distortion and torque pulsations, as well as providing lower volts to earth on an earth fault.

The propulsion motors are dual wound, six phase machines supplied by ALSTOM Electrical Machines. They are water cooled and include self-contained white metal bearings. In the event of cooler failure, the motors can still operate by drawing machinery space air through emergency cooling doors on the motor coolers. DC excitation is provided to the machines, from a dedicated DC field converter mounted within the drive.

The drive cubicles are direct water cooled using a self contained, low conductivity water circuit, and a water to water heat exchanger to transfer heat to the ship's water cooling. This allows for a compact, quiet and efficient system at a good power density.

The drive control is fully digital, using the Sigma drive controller, which provides all the control and monitoring requirements for the power, cooling and external interfaces, allowing autonomy from the Power Management System (PMS).

Harmonic filtering

Two harmonic filters are included at the 6.6kV level, one connected to each of the aft and mid switchboards, to ensure electrical proximity to the main propulsion converters. The filters are designed to meet the close harmonic tolerances as required by DEFSTAN 61-5 Pt 4 Issue 2.

Ship services

The two ship services transformers provide the supply to the 440V distribution system which support all of the ship's services, including hotel, weapon and communication systems. No motor generator sets are used. ALSTOM Drives & Controls has, therefore, to guarantee the quality of the 440V supply, in terms of voltage, frequency and harmonic content.

These requirements are more strict than those required by Lloyd's rules and are covered by one of the MoD's own Defence Standards DEFSTAN 61.5-5 Pt 4 Issue 2.

Pushing COTS equipment further

The equipment supplied is a derivative of COTS equipment. Design attention has been paid to certain specific additional issues, most noticeably 440V supply quality and shock requirements.

440V supply quality DEFSTAN requirements

One of the major specification requirements was to guarantee the quality of the 440V supply to the more stringent DEFSTAN 61-5 Pt 4 requirements rather than those of Lloyds Register.

The large amount of 440V required to be of this standard (potentially 10MVA) made the standard approach of Motor Generator (MG) sets impractical in terms of cost and space requirements. By simply using the transformers in lieu of MG sets, this meant that the HV system would also have to meet the exacting DEFSTAN requirements.

The system makes use of low reactance ship services transformers, with careful choice of cabling, and setting of AVRs to maintain voltage within tolerance. Requirements for system frequency are met by isochronous parallel operation of all the generators, with load sharing lines connecting all of the digital generator governors.

Harmonic content requirements are met by a combination of the 12 pulse drive arrangement and the two passive harmonic filters mounted on the HV system. These ensure that the harmonics generated by the large drives are removed at source, before they can transfer to the LV system.

This approach ensures that the voltage and frequency remains within specification and is not reliant on the power management system with its inherent time lags.

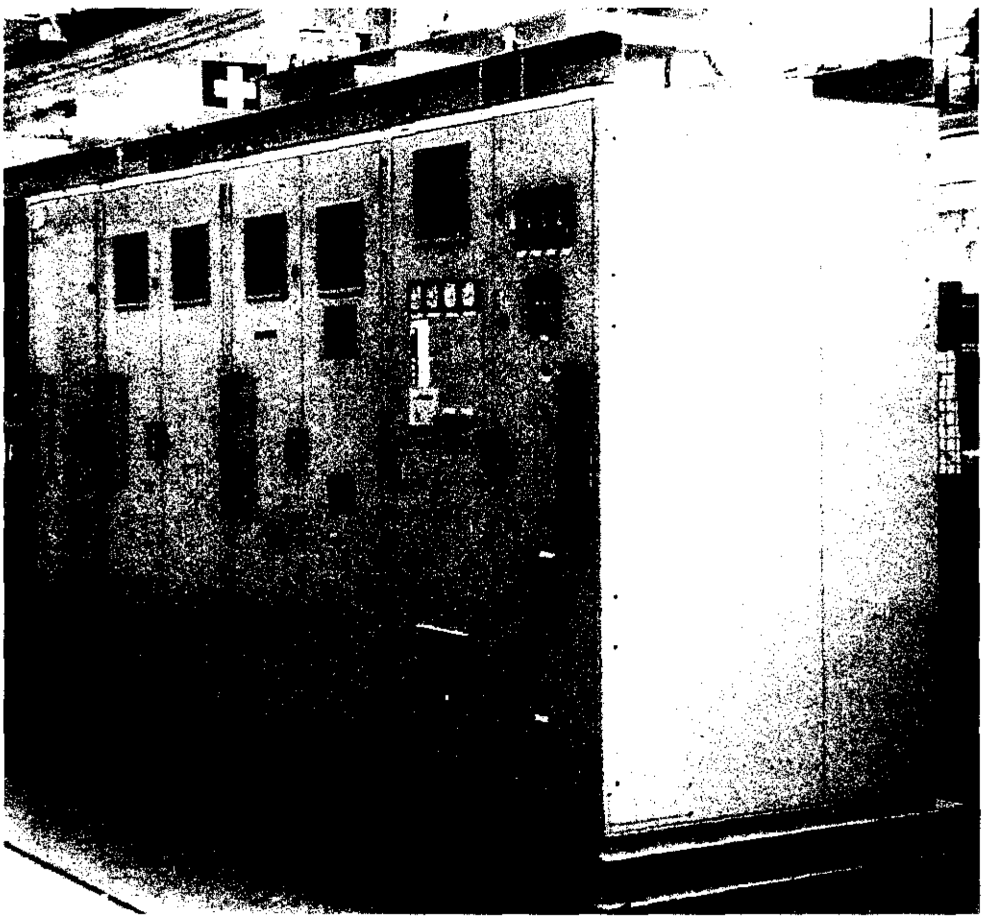

FIG.8 - S2000 WATER COOLED SYNCHROCONVERTOR MODIFIED FOR CAPTIVE SHOCK

Shock

Whilst all of this equipment has previously been approved to the marine standards required by classification societies such as Lloyds and DNV, the required shock requirement takes was an additional design consideration.

Shock requirements were included in the specification, which necessitated some modification to the standard marine equipment, in such areas as mounting arrangements and frame construction.

The LPD Synchroconverter cubicle suite, modified for this requirement, can be seen in (FIG.8). Much of the equipment is fitted on shock mounts, as well as containing extra bracing and bonding over and above normal commercial marine requirements.

HV switchboard frameworks are of a single piece of welded construction, and contain all of the generator AVRs and digital governors within the main body (FIG.9).

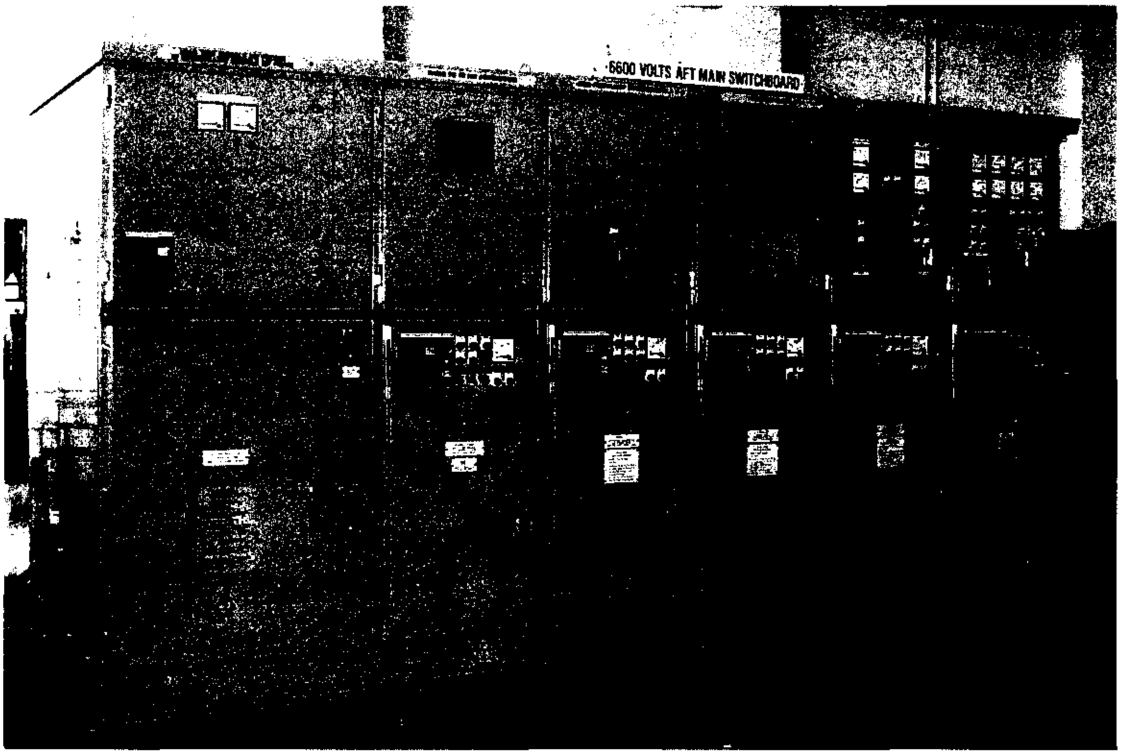

FIG.9 - SINGLE WELDED FRAME CONSTRUCTION HV SWITCHGEAR (LPD AFT BOARD)

Conclusion

The LPD full electric propulsion system is designed to meet both the requirements of Lloyds Register and the more exacting requirements of the Royal Navy in certain areas.

It meets these requirements whilst using proven COTS equipment and still remains a proven, relatively simple yet robust design, both at the system and equipment level. Much of this results from both technical and TLC requirements being understood and included into the design from the beginning, rather than included as additions to the contract at a later date. This was achieved through close liaison between the system designers, VSEL and the Royal Navy, before the tender stage and this process is continuing.

We now look forward to the installation and commissioning phase of the system as the vessel build programme progresses.