DYNAMIC POSITIONING CONFERENCE
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POWERPLANT SESSION

The Deepwater Horizon
A Unique 10,000-ft Water Depth Dynamically Positioned Semisubmersible Drilling Vessel

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Introduction

Drilling deepwater prospects in areas subjected to tropical storms and high velocity loop currents is a challenge. As shown in Figure 1, VASTAR Resources (VASTAR) has several Gulf of Mexico prospects in water depths up to 10,000-ft and some of these blocks are subjected to loop currents in addition to tropical storms. Until now, operators have been forced to suspend operations when these storms and high velocity loop currents approach the location and then wait until the seas and currents subside before resuming operations. This suspension in operations, which can last for days to weeks, results in costly downtime.

VASTAR and Reading & Bates Falcon (R&BF) are preparing to meet this challenge. VASTAR contracted with R&BF to build the Deepwater Horizon, a dynamically positioned semisubmersible capable of conducting both drilling and completion operations in 10,000-ft of water while subjected to 60-kt winds, 26-ft significant waves and a 3.5-kt loop current. The rig is 374-ft long and 256-ft wide (Figure 2). Displacement at the 75.6-ft operating draft is 52,345 MT. Load carrying capacity will exceed 8000 MT.

This paper will focus on the power system to be installed on the rig. Station keeping, drilling equipment, riser management, simultaneous rig operations, rig design and rig motions are all subjects suitable for future papers.

Power Requirements

The primary power consumers on a dynamically positioned (DP) drilling vessel are the thrusters (station keeping) and the drilling loads. The power requirements for both loads were carefully analyzed to size the vessel’s power plant. The impact of having one engine/generator set down for maintenance/repair or losing an entire engine room due to fire or flooding was also evaluated.

Station Keeping Power Requirements

Thruster sizing and the associated power demands were based on VASTAR’s design requirement to maintain station during 60-kt winds, 26-ft. significant waves, and a 3.5-kt current with one thruster down for repair/maintenance. R&BF conducted model tests, thruster interference tests, and computer simulations to determine total thrust requirements. Results indicated that eight 7370 HP (5500 kW) azimuthing thrusters would satisfy the demand while allowing for sufficient redundancy and inter-action losses. As shown in Figure 3, the thrusters in each corner of the rig
are offset to minimize thruster-thruster interference effects when both thrusters are oriented along the rig’s centerline (when headed into strong currents or when the rig is underway). Loss of thrust due to thruster-thruster interference effectively increases the commanded thrust requirements and power requirements to the thrusters.

- **VASTAR Design Conditions (60-kt Winds, 26-ft Significant Waves, 3.5-kt Current)**

  Peak power demands to the thrusters occur when the rig is headed into a 3.5-kt loop current and 60-kt winds and 26-ft significant waves approach the rig from any direction within a sector bounded by the port bow quarter around to the starboard bow quarter (345 degrees around to 45 degrees relative to the bow heading) as shown in Figure 4. Under these environmental conditions, the rig’s power plant must be capable of delivering approximately 31.3 MW to the thrusters in order to maintain station. Power requirements decrease as the wind and waves move around toward the stern.

  Maximum potential power consumption with eight thrusters operating is 44 MW, which exceeds peak demand for the maximum design condition, as well as total installed power. Based on VASTAR’s requirement to maintain station with one thruster down for maintenance or repairs, thruster power demands equal approximately 80% of maximum capacity with seven thrusters on line, which provides a comfortable measure of redundancy.

- **10-Year Gulf of Mexico Hurricane (60-kt Winds, 26-ft Significant Waves, 1.6-kt Current)**

  Power demands by the thrusters during 60-kt winds, 26-ft significant waves, and a 1.6-kt current are shown in Figure 5. As shown, approximately 23 MW is required for weather approaching the rig on the port quarter around to the starboard quarter.

- **99.9% Gulf of Mexico Environment (50-kt Winds, 19-ft Significant Waves, 1.2-kt Current)**

  The polar plot shown in Figure 6 illustrates the thruster demands during weather anticipated to be exceeded only 0.1% of the time. Under these conditions, the maximum power demand is 16.3 MW or about half of the power required to meet the VASTAR design conditions.

  The VASTAR design criteria established the thruster size and associated power requirements. The other two examples illustrate the power levels to be anticipated during less severe environmental conditions.

**Drilling/Hotel Power Requirements**

The remaining power demands come from drilling and hotel loads. R&BF reviewed their records to determine average and maximum power demands during various drilling operations. These values were then corrected to reflect equipment to be installed on the **Deepwater Horizon**. Hotel and marine loads were also reviewed.
Average and maximum anticipated drilling loads for top hole drilling, normal drilling, tripping and back reaming are shown in Table I. Average drilling loads vary from 2.5 MW for normal drilling operations to 3.5 MW for top hole drilling. The average drilling load is about 3.0 MW.

Maximum (peak) drilling loads are anticipated to exceed 9 MW (Table I).

Hotel and marine loads are anticipated to be approximately 2.5 MW.

### Table I
**Electrical Load Analysis - Drilling**

<table>
<thead>
<tr>
<th>Description</th>
<th>Average, MW</th>
<th>Maximum, MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Hole Drilling</td>
<td>3.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Normal Drilling</td>
<td>2.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Tripping</td>
<td>3.0</td>
<td>7.4</td>
</tr>
<tr>
<td>Back Reaming</td>
<td>3.0</td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>3.0</strong></td>
<td><strong>8.5</strong></td>
</tr>
</tbody>
</table>

**Deepwater Horizon Power Plant Requirements**

The maximum power plant requirements were established by considering the maximum anticipated drilling load (9.2 MW for normal drilling), the maximum power consumption by the thrusters during the VASTAR design storm (31.3 MW), and the anticipated hotel load (2.5 MW) as shown in Table II. These studies showed that if the maximum drilling loads occur at the same time as the maximum station keeping requirements, the *Deepwater Horizon* power plant should be capable of delivering 43 MW to meet VASTAR’s criteria. The probability of both maximum demands occurring at the same time was considered to be low. In addition, the power plant can operate at 110% (46.2 MW) on an intermittent basis (1-hr. in each 12-hr. period) which can effectively absorb temporary dynamic overloads.

Based on these results, R&B elected to install six 7 MW (11 kV) main diesel engine/generator sets capable of generating a total of 42 MW.

### Table II
**Electrical Load Analysis – Design Load Level**

<table>
<thead>
<tr>
<th>Drilling Maximum, MW</th>
<th>Hotel MW</th>
<th>Station Keeping Design Storm MW</th>
<th>Total Load MW</th>
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</thead>
<tbody>
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</table>

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As shown in Table III, the power plant is sized so that 4 – 5 diesel engine/generator sets should be able to handle the daily drilling and station keeping loads for operations in the Gulf of Mexico. For periods when the maximum anticipated VASTAR storm loads occur at the same time as the maximum anticipated drilling loads, all main diesel engine/generator sets must be on-line.

<table>
<thead>
<tr>
<th>Description</th>
<th>Drilling Average, MW</th>
<th>Hotel MW</th>
<th>Station Keeping 99.9% Storm MW</th>
<th>Total Load MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Hole Drilling</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Drilling</td>
<td>9.2</td>
<td>2.5</td>
<td>31.3</td>
<td>43.0</td>
</tr>
<tr>
<td>Tripping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Reaming</td>
<td></td>
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</tbody>
</table>

The main power plant is located aft of the moonpool as shown in Figure 7. A unique feature of this rig is the concept of installing each main diesel engine/generator set in a separate compartment divided by A-60 bulkheads so that fire or flooding in any main generator compartment will not affect the others. An 11 kV switchboard is located in each of the six engine compartments (switchboards number 1-6). Each 11 kV switchboard feeds a 480 V bus for its associated engine auxiliaries and thruster loads.

In addition to the six switchboards located in each of the main engine compartments, there are two additional 11 kV switchboards (number 7 and 8) located in separate A60 compartment as shown in Figure 8. These two switchboards rely on a connection to another switchboard for power.

One thruster is connected to each of the eight switchboards. Thruster #1 and the 50% of the primary drilling drives (Active heave compensated drawworks, top drive, mud pumps, cement pumps, and the auxiliary drawworks) are connected to switchboard # 8.

Switchboard #7 carries thruster #8 and the remaining 50% drilling drive loads. The normal operating procedure will be to have all eight switchboards connected in a ring main arrangement.
so that each main diesel engine/generator set can feed the switchboard ring. This approach will permit the power management system to optimize on the number of main generators on line in order to carry the required loads. Two bus-tie breakers, one on each side of each switchboard, connect individual switchboard to complete the ring. One of the bus-tie breakers has a synchronizing element installed that permits the connection of a newly energized switchboard to a live switchboard.

Each switchboard feeds two quadrant 480V switchboards for drilling, hotel and marine loads.
Loss of a diesel engine/generator set

With this arrangement, loss of one diesel engine/generator set due to repair/maintenance will not interrupt operations unless total demand approaches 35 MW, the maximum power for seven main units on line (5 x 7 MW = 35 MW). The thruster and 480V bus can be back-fed from the ring main.

Loss of an engine room

Loss of an engine room with its associated diesel engine/generator set and switchboard due to fire or flooding will cause loss of the thruster and the 480V bus loads assigned to that switchboard.

Fuel Oil System

Fuel for each engine is supplied through dual, independent manifolds - one outside and aft of the engine rooms and one outside and forward of the engine rooms. Each supply line from the manifold to the engine has an isolation valve, which can be closed manually by rig personnel or automatically in the event of a fire in an engine room prior to CO₂ release.

The manifolds have isolation valves at each end and in the center that permits routine maintenance to be carried out.

There are eight fuel oil storage tanks - four in the port pontoon and four in the starboard pontoon.

Main Saltwater Cooling System

There are four main saltwater (SW) pumps in each pontoon – two forward and two aft. There are also two pump rooms in each pontoon – one forward and one aft. One saltwater pump is located in each pump room and one is located in an adjacent thruster room (thruster rooms #1, 4, 5, and 8). Each of these spaces has its own sea chest and salt water suction. The two saltwater pumps in each end of the pontoons are manifolded together and feed a salt water ring main in the upper hull

The engine rooms are circled by a SW cooling ring main much like the fuel system. One manifold is located aft of the engine rooms running port to starboard and another manifold is located forward of the engine rooms. In order to balance the pump loads, the three engine rooms on the port side will be serviced from the aft manifold and the three engine rooms on the starboard side will be fed by the forward manifold. In the event of a problem, valving allows each engine room to be fed by either the forward manifold or the stern manifold.

Blockage of any one sea chest or strainer will only effect one of the eight main pumps.
Engine Fresh Water Cooling System

Each engine room has a separate fresh water cooling system for the diesel engine in that compartment.

Emergency Generator

There is no separate emergency generator. Any main engine is configured to become the Emergency Generator to feed the EG Switchboard when required.

Power Management System

The **Deepwater Horizon** will be equipped with a power management system to control power generation and power distribution in order to assure that adequate and reliable power is continuously available for the thrusters, drilling equipment, and hotel loads.

Functions of the power management system (PMS) include:

- Continuous monitoring of the load situation and initiation of a start or shut down command to the engine/generator sets, as required, to maintain sufficient power.

When power demand reaches a preset threshold, the PMS will send a command to start another generator. The PMS will first start a generator, connect it to the switchboard and then start the consumer. The start signal is a time relay function, which allows the start signal to be given for maximum of 5 seconds. If the engine fails to reach operating speed within 20 seconds, a start failure alarm is given and the next stand-by engine is started. If a synchronizing time-out occurs, the PMS will start the next stand-by generator. Shutdown of an engine is performed if the engine fails to meet the criteria for acceptance. The PMS in this case will give the start order to the next stand-by engine. If all generators fail, the PMS will instigate a blackout recovery.

- Monitoring the condition of each diesel engine/generator set and shut down specific generator sets in response to alarm conditions.

- Controlling the load sharing of the generator sets on-line.

- Controlling the regenerated power limit for the drilling drawworks equipment during tripping operations.

- Providing system blackout protection.

Should there be a system blackout the power management system also provides a blackout restart sequence which will automatically restart the power system and provide power to the thrusters in a minimal time in order to keep the dynamic positioned vessel on location.
A traditional load-shed system is not practical on this vessel because the majority of the electrical loads are due to the thrusters and the drilling systems. Drilling loads and thruster loads will be managed and reduced, if necessary, so there may be a small excursion of position until the next generator is on-line.

**Blackout Prevention**

Electrical blackouts result when demand exceeds supply. Most offshore drilling rig blackouts occur when engine/generator sets unexpectedly shut down without warning due to problems such as fuel system failure, mechanical failure, bus failure, control system failure, or human error. This type of shutdown is more difficult to avoid than the type caused by excessive demand, but it may be effectively handled if the power management system operates rapidly to reduce electrical demand to within the capacity of the remaining generators.

Other blackouts occur because demand increases unchecked until the capacity of the on-line engine/generators is exceeded. As demand increases, the engine/generator sets must supply more power, until they reach and/or exceed their capacity. When an engine/generator exceeds its peak power capacity (kW) or its electrical capacity (kVA), the engine overheats or the generator goes over current. As soon as the first engine shuts down due to over temperature or over current, another on-line engine/generator set will quickly exceed its thermal or current capacity and shut down. Eventually all units will shut down. This class of blackout can be avoided by monitoring total energy demand in comparison to available supply and quickly reducing loads to coincide with online capacity for sudden engine/generator trips.

**Failure Mode and Effect Analysis (FMEA)**

A preliminary FMEA was performed to identify single point failures that could shut down the system. A detailed FMEA analysis is being performed at this time.

**Shipyard/Delivery Date**

The rig is being built by Hyundai Heavy Industries (HHI) in Ulsan, Korea. Delivery is scheduled for November, 2000. After sea trials and acceptance testing, the rig will be brought to the Gulf of Mexico to begin a 3-yr. contract with VASTAR. VASTAR also has three one-year options.
Figure 1
Vastar Resources, Inc.
Gulf of Mexico
Deepwater Concessions
Deepwater Horizon
Figure 3
R&BF Deepwater Horizon Thruster Locations
Deepwater Horizon
Power Requirements

Figure 4
Thruster Power Requirements
(60-kt winds, 26-ft significant waves, 3.5-kt current)
Figure 5
Thruster Power Requirements
(60-kt winds, 26-ft significant waves, 1.6-kt current)
Deepwater Horizon Power Requirements

Current

Wind & Waves Variable Angle

Thruster Power Requirements (50-kt winds, 19-ft significant waves, 1.2-kt current)

Figure 6
Figure 7
R&BF Deepwater Horizon
Engine Room Locations
Figure 8
R&BF Deepwater Horizon
I-Line Electrical Schematic