Status and Inventions in Electrical Power and Thruster Systems for Drillships and Semi Submersible Rigs

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Outline

- Introduction
- Electric Power System Description
- Experiences
  - Response time dynamics of load reduction/blackout prevention
  - Diesel engine governor and AVR fault tolerance
  - Special characteristics of electric installations for ships and rigs
  - Harmonic distortion
- Technology Evolution
  - Electric Power Generation and Distributions
  - Variable Speed Drives
  - Electrical Podded Thrusters
Deepwater Drilling Vessels

- More than 25 deepwater drilling vessels build after 1997
  - Drillships and Semi Subs
- Dynamic Positioning
  - DP2 or DP3, (or “DP2.5”)
- Electrical System
  - Medium Voltage, 6 or 11kV
  - 2, 4, 6, 8-split
- Variable Speed Thrusters
  - Electrically driven with Current Source or Voltage Source Converters
  - Mechanical or podded azimuthing thrusters
- Drilling Drives
  - DC (SCR) drives
  - PWM Single or Multidrive
  - Regenerative or not
Electric Power System for Drillship

Drilling package
AC Multidrive
El. Power System for Semi Submersible

Drilling package
AC Multidrive
Black-out
Prime Mover - Diesel Engine

Graphs showing specific fuel oil consumption (g/kWh) and total load (% MCR) for different configurations of generators.
Power Management Power Reduction

- Power reduction, critical situation
- Power reduction, non-critical
  - Auto start
  - Auto stop

Variables:
- $P_{A,\text{normal}}$
- $P_{A,\text{start}}$
- $P_{A,\text{stop}}$
- $P_{A,\text{available}}$

Events:
- $T_{\text{stop}}$
- $T_{\text{start}}$

Legend:
- $P_{A,1}$ - $P_{A,N}$
- Load Reduction/Shedding
Black-out Prevention

PMS functions:
- Automatic start/stop of diesel generators
- Calculation of available power on each bus
- Load control
- Black-out prevention and recovery
- Heavy consumer handling
Black-out Prevention Functions

- **Thruster and thruster drives:**
  Variable speed FPP thrusters must have a load reduction scheme, either monitoring the network frequency and/or receiving a fast load reduction signal from the power management system, either as a power phase-back signal, maximum power limitation signal.

- **Drilling drives:**
  Similar to the requirements of the thruster drives, with built-in priorities for the individual drilling drives.

- **Power management system:**
  The power management system includes blackout prevention with load reduction/load shedding functionality.

- **Dynamic positioning system:**
  The dynamic positioning system is also equipped with a power limitation function, normally based on a permitted maximum power consumption signal from the power management system. Generally, this has shown to be effective in avoiding overloading of the running plant, but not fast enough to handle faults and loss of diesel-generator sets.
Time before under-frequency (Illustrative)

- Fixed speed CPP load red
- DP power limitation
- PMS blackout prevention
- VSI Drives FPP load red

Risk for Blackout

- Worst case overload
- Load x MCR

- 100%
- 200%
- 300%

- 10 sec
- 5 sec
- 1 sec
- 0.5 sec
- 0.1 sec
Governor or AVR Faults

AVR faults:
- Under excitation
  - Inductive (kVAR import)
  - Under voltage
  - Min kVAR
- Over excitation
  - Capacitive (kVAR) export
  - Over voltage
  - Max Amp
- Intermittent faults
  - Rear
  - Combinations of over and under excitation
Governor or AVR Faults

Governor faults:
- To low fuel
  - kW reduces
  - RPM may reduce
- To excessive fuel
  - kW increases
  - RPM may increase
- Intermittent faults
  - Rear
  - Combinations
Diesel Generator Monitoring System

Voting algorithm

Correlation algorithm

Trig limit and time delay settings

Demagnetize
Disconnect
Excitation Alarm
Excitation Fault

I1-I4
U1-U4
Q1-Q4
Ii
Ui
Qi
Electric System Characteristics

- Voltage distribution
- Voltage gradient

Winding with linear voltage distribution:
- Voltage distribution
- Voltage gradient

Winding with non-linear voltage distribution:
- Voltage distribution
- Voltage gradient
Harmonic Distortion
Harmonic Distortion
Harmonic Distortion (Examples)

<table>
<thead>
<tr>
<th>NB: With High Gen Load</th>
<th>6-pulse</th>
<th>12-pulse</th>
<th>Q24-pulse</th>
<th>24-pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>THD Main bus</td>
<td>10..13%</td>
<td>6..8%</td>
<td>&lt;5%**</td>
<td>&lt;4%</td>
</tr>
<tr>
<td>THD Distribution bus</td>
<td>&lt;5%*)</td>
<td>&lt;6..7%</td>
<td>&lt;5%**</td>
<td>&lt;4%</td>
</tr>
</tbody>
</table>

*) with harmonic filter
**) closed bus tie
12-pulse Drives

Medium Voltage
Single Drive for
Thrusters and Propulsion

Low Voltage
Multi Drive for
Drilling, Winches, etc.
Semiconductors

IGBT Module  
(for low voltage drives)

IGCT Component  
(for medium voltage drives)
Drive Technology Map (Indicative)

- Motor Power: 2,000, 9,000, 10,000, 16,000, 27,000, 30,000, 33,000, 37,000, 40,000
- Motor Voltage: 315, 690, 1.0, 1.5, 1.8, 2.4, 3.3, 4.5, 6.0, 6.9
- VSI: Voltage Source Inverters with PWM or DTC
- CSI: Current Source Inverters with Thyristors
- Cyclo: Direct Converter with Thyristors

VSI: Voltage Source Inverters with PWM or DTC
CSI: Current Source Inverters with Thyristors
Cyclo: Direct Converter with Thyristors
Podded Thruster for Drilling Vessels

FP Propeller
Shaft seal protection cone
Propeller side bearing shield
Propeller side bearing
Power & signal cables + pipes
Shaft sealing
Rotor
Stator
Maintenance brake
Thrust bearing
Thrust bearing shield
Strut
Summary

- The fleet of deepwater drilling rigs has generally performed well
  - Design, engineering, construction
  - Crew
  - Equipment selection
- Electric power generation and distribution
  - Experiences
- Technology evolution
  - Design improvements
  - Computerization
  - MV IGBT and IGCT converters
  - Podded thrusters