DYNAMIC POSITIONING CONFERENCE
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POWER SESSION

DP3 Class Power System Solutions for Dynamically Positioned Vessels

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Siemens Oil & Gas
Siemens Oil & Gas
Integrated Systems & Solutions

DP3 Class Power System Solution for Dynamically Positioned Vessels

Stig Settemsdal & Damir Radan
DP3 Class Power System for Dynamically Positioned Vessels

Design Background

Power systems configured and operated in a closed ring was a new requirement from several clients before development start. Focus on high fault integrity and improved fuel economy.

IMO resolution 645:

*Bus-tie breakers should be open during equipment class 3 operations unless equivalent integrity of power operation can be accepted according to 3.1.3*

Challenge:

Build in sufficient protection and safety in the power system design in order to achieve the necessary fault integrity as required by IMO and class.
1. **Design Principles for DP3**
   - Traditional power system
   - New fault tolerant power system based on “self sustained islands”

2. **Advanced Protection Functionality**
   - Protection scheme with zone protection
   - Protection system considering hidden faults
   - IEC 61850 Based protection and Interlocking

3. **Generator Performance Controller - GPC**
   - Dynamic study

4. **Some Extended Functionality**
   - Enhanced Fault Ride Through Capability
   - Blackout recovery

5. **Operational efficiency and flexibility**
   - Fuel savings
   - Engine maintenance costs
   - Operational flexibility
DP3 Class Power System for Dynamically Positioned Vessels
Traditional Power System

Fault integrity based on: Segregated top-level of the power system according to fire and flooding segregation
DP3 Class Power System for Dynamically Positioned Vessels New fault tolerant power system

Fault integrity based on: Limited amount of interconnections on lower level distribution and advanced protection scheme on top level
Protection of Ring Main Units – Time Graded Selectivity

Advantages:
- No cross connections, no communication links

Disadvantages:
- Relatively high fault clearing times → dynamic stability
- No hidden faults considered

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DP3 Class Power System for Dynamically Positioned Vessels Advanced Protection Functionality – Closed Ring scheme

Differential-protection topology combined with other protection

Advantage:
- Un delayed (Immediate) fault clearing
- All protection included (O/C 50/51 and directional 67)

Disadvantage:
- No – as pilot wires are substituted with FO links – IEC 61850
Protection scheme with zone protection all over

- Busbar Differential Current and Ground Fault Current Protection
- Bus-tie Cable Differential and Ground Fault Current Protection
- Transformer Protection
- Transformer 4th Winding Protection
- Breaker Failure Protection
- Breaker Trip Coil Supervision
- CT & VT extended monitoring
- VT fuse failure monitoring
Protection system considering hidden faults

- Generator protection: backup: 50/51
- Generator protection: 87
- Bus-bar protection: back-up: 67
- Bus-bar protection: 87
- Sub-section protection: back-up: 50BF
- Drilling and distribution protection: 50/51
- Thruster protection: 50/51
- Utilities protection: 50/51
- Bus-tie protection: 87

DP3 Class Power System for Dynamically Positioned Vessels Advanced Protection Functionality – Closed Ring scheme

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Circuit Breaker Monitoring and Supervision

Breaker Trip Coil Supervision
Circuit supervision with two binary inputs:
- Detects interruptions in the trip circuit and loss of control voltage
- Supervises response of CB using the position of the circuit breaker auxiliary contacts

50 BF – Breaker Failure to Trip Supervision

The time delay is entered at address 7005 TRIP-Timer. This setting should be based on the maximum circuit breaker operating time plus the dropout time of the current flow monitoring element plus a safety margin which takes into consideration the tolerance of the time delay. Figure 2-87 illustrates the time sequences.

- Detectors interuptions in the trip circuit and loss of control voltage
- Supervises response of CB using the position of the circuit breaker auxiliary contacts
IEC 61850 Based protection and Interlocking

<table>
<thead>
<tr>
<th>Type</th>
<th>Applications</th>
<th>Performance Class</th>
<th>Transmission Time</th>
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<tr>
<td>1A</td>
<td>Fast Messages Trip</td>
<td>P1</td>
<td>10 ms</td>
</tr>
<tr>
<td>1B</td>
<td>Fast Messages</td>
<td>P1/P3</td>
<td>3 ms</td>
</tr>
<tr>
<td></td>
<td>Other</td>
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<td>Low Speed</td>
<td>P2/P3</td>
<td>100 ms</td>
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<td>4</td>
<td>Raw Data</td>
<td>P1</td>
<td>500 ms</td>
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<tr>
<td>5</td>
<td>File Transfer</td>
<td>P2/P3</td>
<td>10 ms</td>
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<tr>
<td>6</td>
<td>Time Synchronization</td>
<td>&gt; 1000 ms</td>
<td>1 ms</td>
</tr>
</tbody>
</table>

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**Generator Performance Controller** shown together with protection devices in the overall system topology

Functions included in the various GPC Levels:
- PMS interface (Level 0,1,2)
- Alarms & Monitoring (Level 0,1,2)
- Monitoring of Generator (Level 1,2)
- Enhanced fault ride through gen. (Level 1,2)
- Monitoring of Diesel Engine (Level 2)
DP3 Class Power System for Dynamically Positioned Vessels
Generator Performance Controller - GPC

Power Management System

LEVEL 0
GPC Module: GATE
PMS Interface and Measurements

LEVEL 1
GPC Module: FADER – G
FAult DEtection (FADER) for Generator

GPC Module: EFORT
(Enhanced FAult Ride Through)
Improves response during and after short-circuit faults

GPC Module: COMMAND (system re-structure)
- Change modes, start new gen-sets, trip faulty gens, split system...
- Minimize RISK of blackout
- Minimize Loss of propulsion
- FMEA based

LEVEL 2
GPC Module: FADER – D
Generator AND Diesel FAult DEtection (FADER)

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DP3 Class Power System for Dynamically Positioned Vessels
Generator Performance Controller - GPC

GPC Module EFORT - Example:
The uncontrolled load recovery makes large stress to the generator:

- Voltage can go over 120% and frequency over 110% → Trip of essential consumers
- Exciter can be over-stressed due to over-voltage uncontrolled
- Very high torque change at shaft and engine coupling

GPC module EFORT can minimize these responses and keep voltage overshoot below 120%
DP3 Class Power System for Dynamically Positioned Vessels
Generator Performance Controller - GPC

Typical AVR – with optimized settings on controller

GPC – EFORT command to AVR after short circuit sensed
Generator diagnosis (Example): Generator under-producing – HIGH

AVR field LOSS:

EASY TO DETECT (values out of limits)

Over-excitation
AVR tripping area

AVR shall TRIP (values out of limits)
Increase in voltage from 1.02 to 1.04 (out of limit set on 1.025)

FAULT: AVR blocked

Active load = 0.3 p.u.

Change in reactive power, tripping healthy generator on negative kVAr must be avoided
Generator diagnosis (Example): Generator under-producing – LOW

AVR field blocked LOW:

DETECTION MORE DIFFICULT (values within the limits)

Within Gen capability curves

Not recommended to operate generators with faults,
If online, gen provide false level of security – Gen might not respond adequately on disturbances and short-circuit faults
DP3 Class Power System for Dynamically Positioned Vessels
Fault Ride Through of Gen-sets - Bolted short-circuit

2 gen-sets online – equally loaded

Direct online (DOL) motor

Torsional oscillation on the shaft due to torque deviation due to Pm and Pe are not in balance < still under 1 p.u. torque
DP3 Class Power System for Dynamically Positioned Vessels
Fault Ride Through of Gen-sets - Bolted short-circuit

2 gen-set online - un-equally loaded

Gen-set are pulled-in by very large synchronous torque – this is the reason why large power oscillation (close to 4 p.u.) exists after the fault.

Pull-in torque is lower – power oscillations after the fault reduced.

Amplitude of torque deviations at the shaft is reduced, under < 1 p.u.

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DP3 Class Power System for Dynamically Positioned Vessels
Fault Ride Through of Gen-sets

- Operating gen-sets with asymmetric (unequal) load sharing increases the risk of high oscillations after a serious fault e.g. when engine at fixed load bias

- GPC module EFORT – Enhanced Fault Ride Through reduces over-excitation from AVR after the fault is cleared and protects gen-set from damage even if operated with asymmetric load sharing or with minor fault

- Gen-set fault should be detected while gen-set operates within normal steady state (class) limits of voltage, reactive power, active power and frequency, etc.

- Operating faulty gen-set online increases the risk of non adequate response of the system and risk of further fault propagation (e.g. fail to trip bus-tie/coupler breaker on short-circuit)

- GPC module FADER – Fault Detection and Response – detects fault on gen-set while system is within limits, and thus reduces any chance of gen-set running over- or under-excited or engines over- or under-producing
Synchronization of generators and Bus-ties

Request for breaker Close Local
Request for breaker Close PMS

Initiate Sync DEIF

Synch-check

Ctrl power Sync

Synch-check

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Fault Ride Through of VSD’s by enabling Kinetic Buffering

Kinetic Buffering – Energy Recovery from rotating mass of the load

Example for 6 pulse VSD
DP3 Class Power System for Dynamically Positioned Vessels
Fault Ride Through of VSD

Simulations results

With Kinetic Energy Recovery

Keep DC volt >80%
Fast Blackout Recovery

No Start-up Inrush at transformers

- PMS running
- PMS Ready for Black Start
- PMS Engine is running
- PMS 5...8 sec.
- PMS 11kV

Sub-section is ON
One Case of fuel consumption calculation:

- Wind speed under 11 m/s for 90% of the time

Propulsion load = 2/3 capacity (Fire & Flood)

(from DP capability)

- Preliminary calculations of fuel consumptions based on weather data is done
- Weather dependent power load (kW) is the most uncertain factor in calculations
- Based on typical engine fuel curve data and efficiency of a Siemens generators
- Fuel consumption study will be done by 3rd party during the next half year
Case Calculation:

- Efficiency curve for rated voltage, frequency and cos φ
- BSFC, g/kWh

Potential for fuel savings

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# FUEL CONSUMPTION

<table>
<thead>
<tr>
<th></th>
<th>Yearly rate [tonns/year]</th>
<th>Rate - day average [tonns/day]</th>
<th>Savings [tonns/year of Max mode]</th>
<th>Savings per year [USD of Max mode]</th>
<th>Savings per 20 years [USD of Max mode]</th>
<th>Rate % [% of Max mode]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens DP3 Closed Ring Min 2 online – Dynpos ER</td>
<td>14994,9</td>
<td>41,08</td>
<td>574,35</td>
<td>$413,528,7</td>
<td>$8,270,573,8</td>
<td>96,31 %</td>
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<tr>
<td>Siemens DP3 Closed Ring Min 2 online - DYNPOS AUTRO</td>
<td>15175,1</td>
<td>41,58</td>
<td>394,11</td>
<td>$283,758,9</td>
<td>$5,675,177,2</td>
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<td>DP3 Closed Ring Min 3 online - DYNPOS AUTRO</td>
<td>15565,0</td>
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<td>Open section bus-ties (2+2+2)</td>
<td>15569,2</td>
<td>42,66</td>
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# GENERAL MAINTENENCE COSTS

<table>
<thead>
<tr>
<th></th>
<th>Run Hours Total [hours/year]</th>
<th>Running hours per engine: assume all 6 engines have equal hours</th>
<th>Overhaul interval for 20 000 running hours of engine [years between overhaul]</th>
<th>Overhaul interval for 25 000 running hours of engine [years between overhaul]</th>
<th>Engine use [% of Max mode]</th>
<th>[% of Max mode]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens DP3 Closed Ring Min 2 online - Dynpos ER</td>
<td>19079,4</td>
<td>3179,9</td>
<td>6,3</td>
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<td>Siemens DP3 Closed Ring Min 2 online - DYNPOS AUTRO</td>
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<td>27840,6</td>
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<td>Open section bus-ties (2+2+2)</td>
<td>27614,8</td>
<td>4602,5</td>
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# RISK OF SOOT ACCUMULATION IN ENGINES

<table>
<thead>
<tr>
<th></th>
<th>Running hours under 30% load [hours]</th>
<th>Run Hours under 30% load - of maximum [% of Max mode]</th>
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<tbody>
<tr>
<td>Siemens DP3 Closed Ring Min 2 online - Dynpos ER</td>
<td>1661</td>
<td>31,41 %</td>
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<tr>
<td>Siemens DP3 Closed Ring Min 2 online - DYNPOS AUTRO</td>
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<td>DP3 Closed Ring Min 3 online - DYNPOS AUTRO</td>
<td>5289</td>
<td>100,00 %</td>
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<tr>
<td>Open section bus-ties (2+2+2)</td>
<td>5289</td>
<td>100,00 %</td>
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</table>

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DP3 Class Power System for Dynamically Positioned Vessels
Fuel consumption calculations

- Fuel savings of up to 3.7% → 400 k USD per year → 8 mil. USD per 20 years

  Engine running hours potential to decrease by up to 30%
  → Maintenance intervals extended for 2 to 2.5 years in average per engine

- Engine operating under 30% load potentially reduced by up to 80%
  → Potentially no need for engine Soot blow-off… (!?)
  → Avoid asymmetric load sharing (No fixed load) → Reduced risk of blackout
  → Lower risk of engine failure to start → Reduced risk of blackout

- Higher operational flexibility
Enhanced Operational Flexibility

<table>
<thead>
<tr>
<th>Engine Room 1</th>
<th>Engine Room 2</th>
<th>Engine Room 3</th>
<th>Total gen online</th>
<th>Min 3 Gen Online</th>
<th>Min 2 Gen Online</th>
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<td>6</td>
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</tbody>
</table>

Example:
Not allowed mode in 3-split – Dynpos AUTRO
Conclusions

ADVANTAGES OF DP3 CLOSED RING SOLUTION

- Enhances system integrity to faults - Less consequences of failures compared to standard DP notations
- Flexible operation according to all class rules, e.g. DP2, DP3 and DPS
- Enhanced vessel station keeping capability with closed ring (max loss of 1/6 of plant, excluding Bus-coupler faults, fire and flooding) – high propulsion availability (all thrusters) assures optimal use of trust
- Reduced fuel consumption up to $\approx 3.7\%$
- Reduced exhaust gas emissions to environment due to lower fuel consumption
- Reduced operating hours up to 30% and
- 80% lower running hours under 30% load $\rightarrow$ reduced maintenance cost for engines and generators
- No need for soot-blow of $\rightarrow$ increased availability of engines applies especially for Dynpos ER
- Increased HSE - Possible to do maintenance of engines/generators with no other engines operating in the same engine room (1 engine room with no running engines)
- Enhanced fault ride through capabilities for generators and VSDs – e.g. reduced risk of generator damage and reduced risk of tripping essential consumers on voltage over-shooting
We are happy to answer your questions!