DYNAMIC POSITIONING CONFERENCE 2009

RISK

Blackout Prevention and Recovery

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ABB

October 13 -14, 2009

Dynamic Positioning Committee

Marine Technology Society

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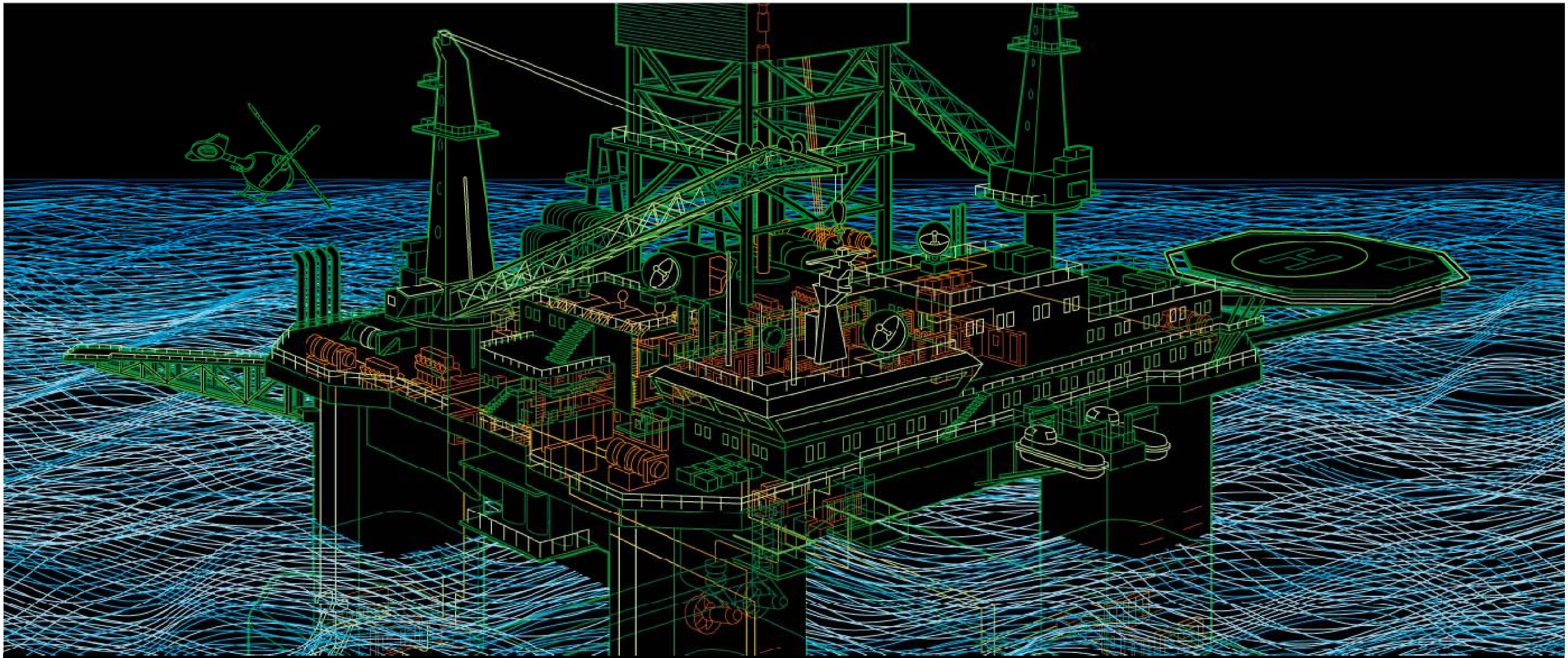


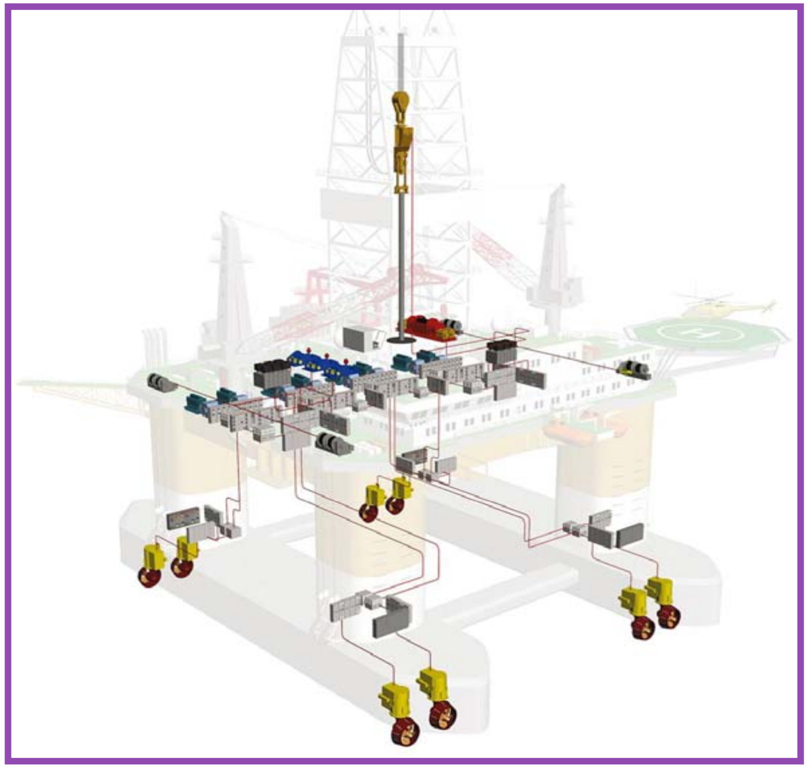
Alf Kåre Ådnanes, DPC 2009 Houston, 2009-10-14

Blackout Prevention and Recovery

Jan Fredrik Hansen, Alf Kåre Ådnanes. ABB

Power and productivity
for a better world™

ABB's Mission for Drilling Vessels
Electric Power Plants, Azipod Thruster, Drilling Drives



Blackout restoration

BLACKOUT

Total loss of electric power generation
Loss of propulsion and station keeping capability
Blackout is a safety risk, and should be avoided
- - -
“Partial blackout”
A term sometimes used to describe
loss of supply to a part of the electric distribution system

Blackout in Marine Power Plants
Example of Reasons and Remedies to Reduce Risk

Fault	Events that may lead to blackout	Remedies
Engine governor fault	High fuel flow to faulty engine: reverse power trip of paralleled engines, over frequency trip	Open bus ties Diesel engine monitoring
Generator AVR fault	Over excitation of faulty generator: under excitation trip of paralleled generators, over voltage trip	Open bus ties Generator monitoring
Operation fault	Inadvertently stopping engines; opening wrong transformer feeders, selecting wrong operation mode	Training, Procedures, Interlocks, Simplicity, Consistency
Sudden trip of engine	Any trip fault, e.g. lubrication fault; step load and overloading of paralleled engines	Fast power reduction Open bus ties
Short circuit	Voltage drop: Tripping of thruster motors, loss of auxiliaries to thrusters	Power ride through Latched LV contactors Open bus ties
Voltage or frequency transients	Large transients after failures or trips, reconfiguration of netork, inrush	Transient analysis and design. Open bus tie

Considerations on the use of Closed Bus-tie

Advantages

- Better utilization of engines, at higher average loads and better fuel efficiency and less maintenance
- More stable power plant with more spinning reserve in parallel, with higher robustness to disturbances
  - Lower peak load variations per engine
  - Reduced risk for cascading trips of engines after disturbances in the network
  - Lower risk of partial blackout

Disadvantages

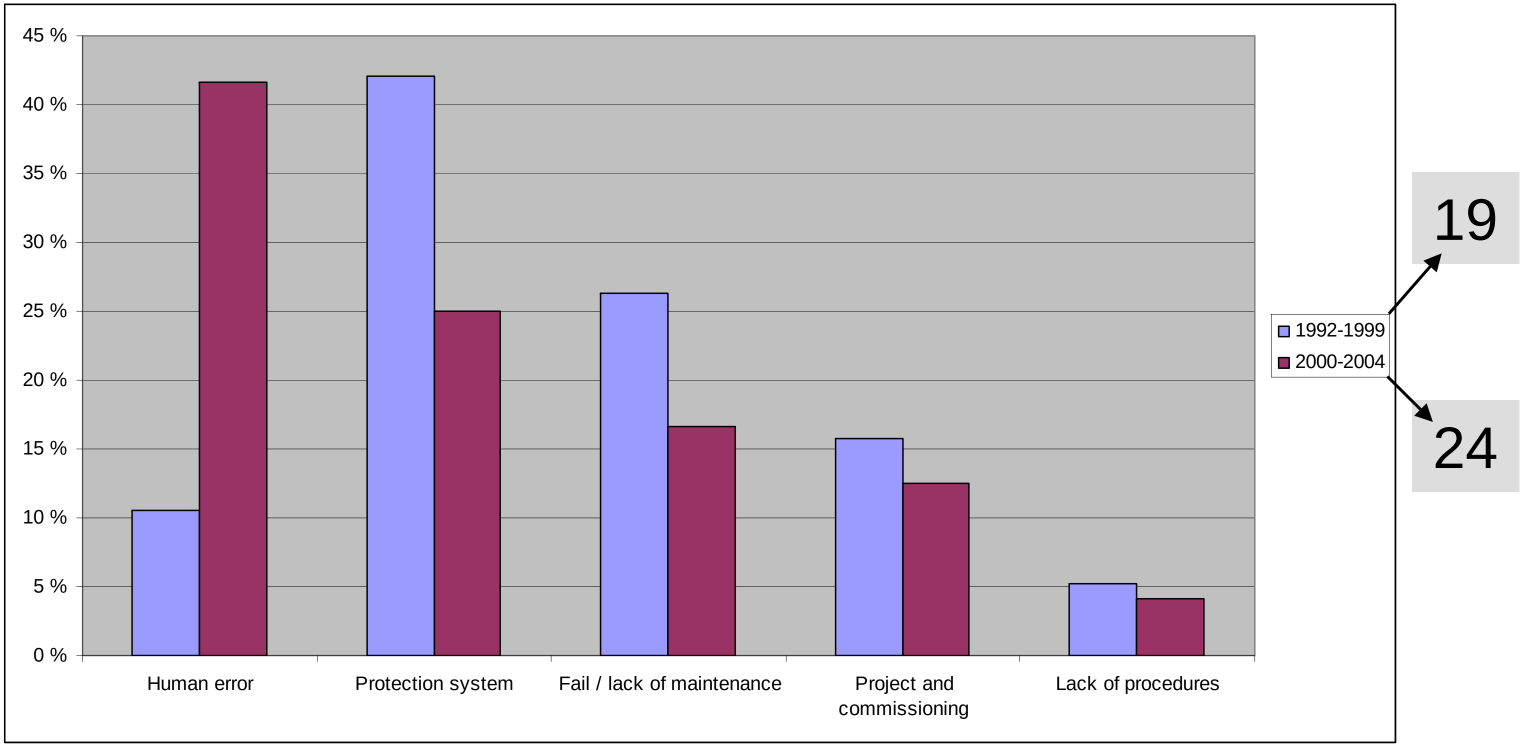
- The power plant is non-segregated
  - Severe faults in the system may cause total blackout
  - Requires more sophisticated monitoring and protection systems, and system design

Note

  - A system can be designed for both operation modes, depending on the operation, consequence of fault, and weather conditions

Statistics
Root Cause for Blackout (by Petrobras)

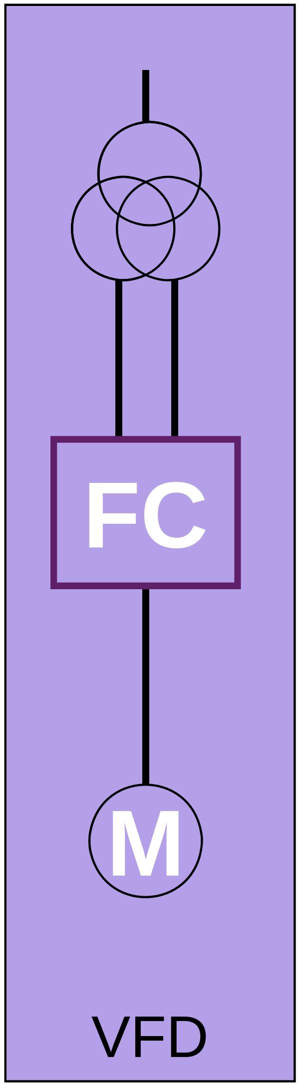
- Relative increase in human/operator errors
- Relative reduction in technical failures



Pallaroro, A.A.:
DPPS – A Petrobras DP Safety Program; Keynote Speech DPC 2005

Important Technical Advances 1990 - 2010
From 4th to 6th Generation Drilling Rigs

- Protection System
  - From analog to digital protection relays
  - Multifunction and programmable logic
  - PLC based monitoring and protection
- System Design
  - Focus on functional integration, established industrial standard practices for interfacing
  - Simplicity in integration, reduced complexity
- Thruster Drives
  - From constant speed electric motors to VFD
  - Voltage source inverters with lower harmonics
  - Fast load control with PWM and DTC
  - Lower kVA loading of the generators
  - Higher reliability and MTBF
- Power Management System
  - Faster controllers
  - Better functional integration with the electric power system



Improvements in Technical Solutions
- But yet Potentials to Enhance Safe Operation

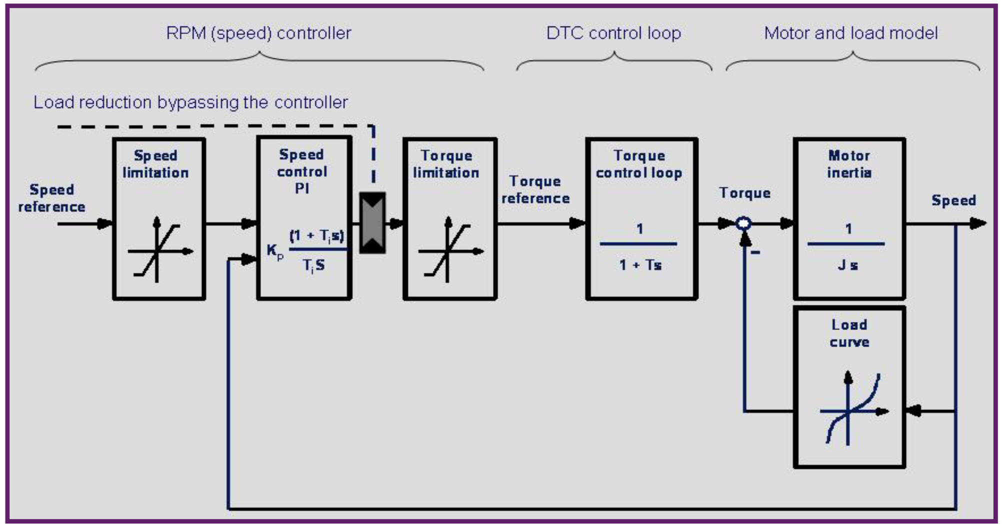
- Fast load reduction
  - Direct Torque Control, DTC, with fast response time
  - Independent frequency monitoring
  - Event based load reduction
- Diesel Engine and Generator Monitoring System (DGMS)
  - Advanced monitoring and protection system
  - First installation in operation since 2005
- Fast Restoration after Blackout
  - Critical review of start-up sequences and time delays
  - Battery backup to reduce start-up times
  - Keep low complexity to reduce chance for failures in start-up sequence

Thruster and Propulsion Control Systems
With Fast acting Load Reduction

Main Features

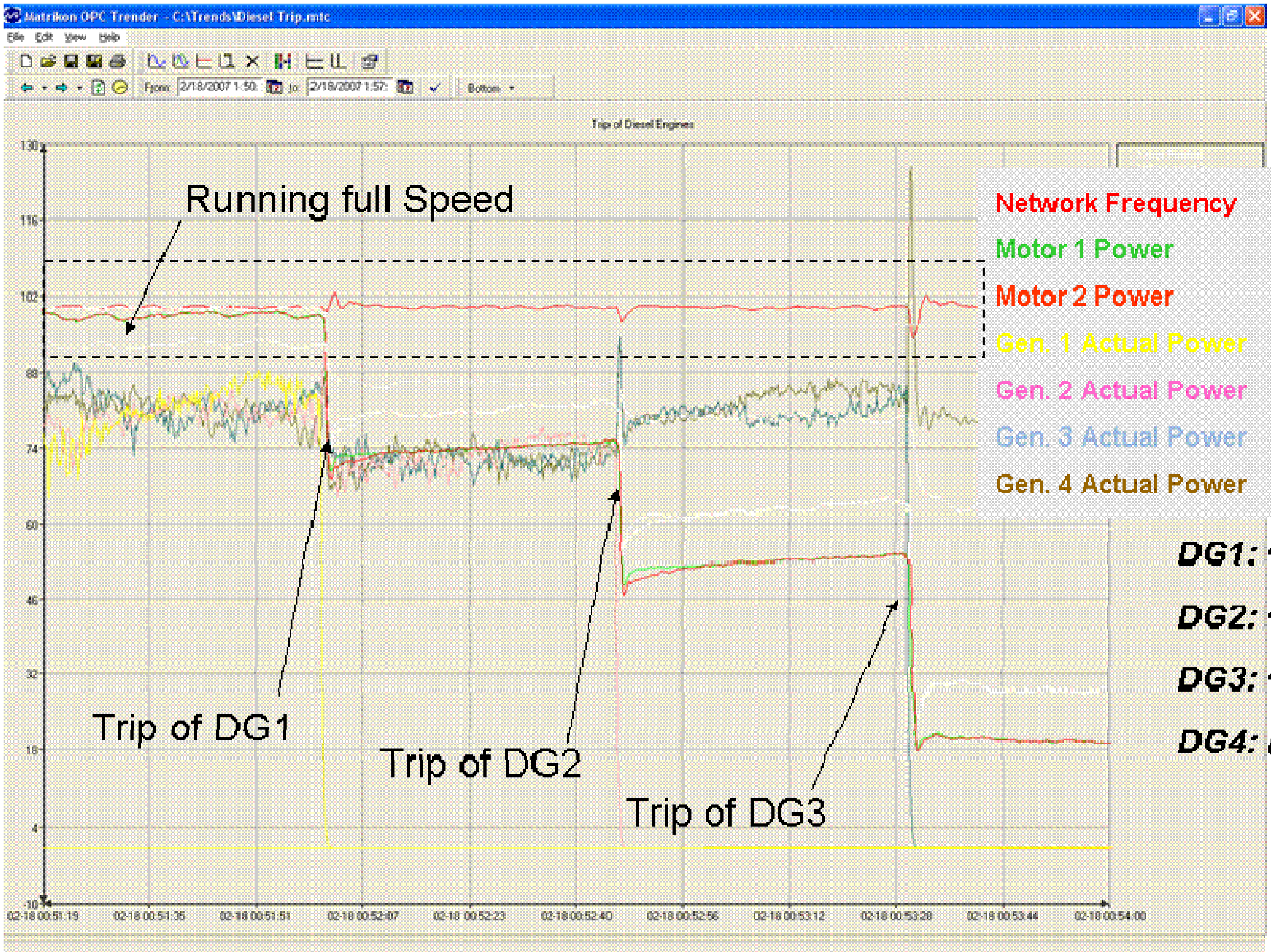
- Control modes:
  - RPM control (DP, transit)
  - Power control (sailing)
- Load reduction functions:
  - Signal from PMS
    - Analog power limit
    - Digital load reduction
  - Independent functions
    - Frequency monitoring
    - Event based (MCB status)
- Interfacing
  - Fast interface to drive DTC controller
  - HW or Bus to DP controller and ICMS

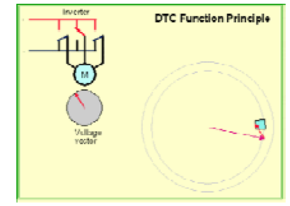
Faster response



Fast Power Reduction

Response time of DTC torque control: ms-range





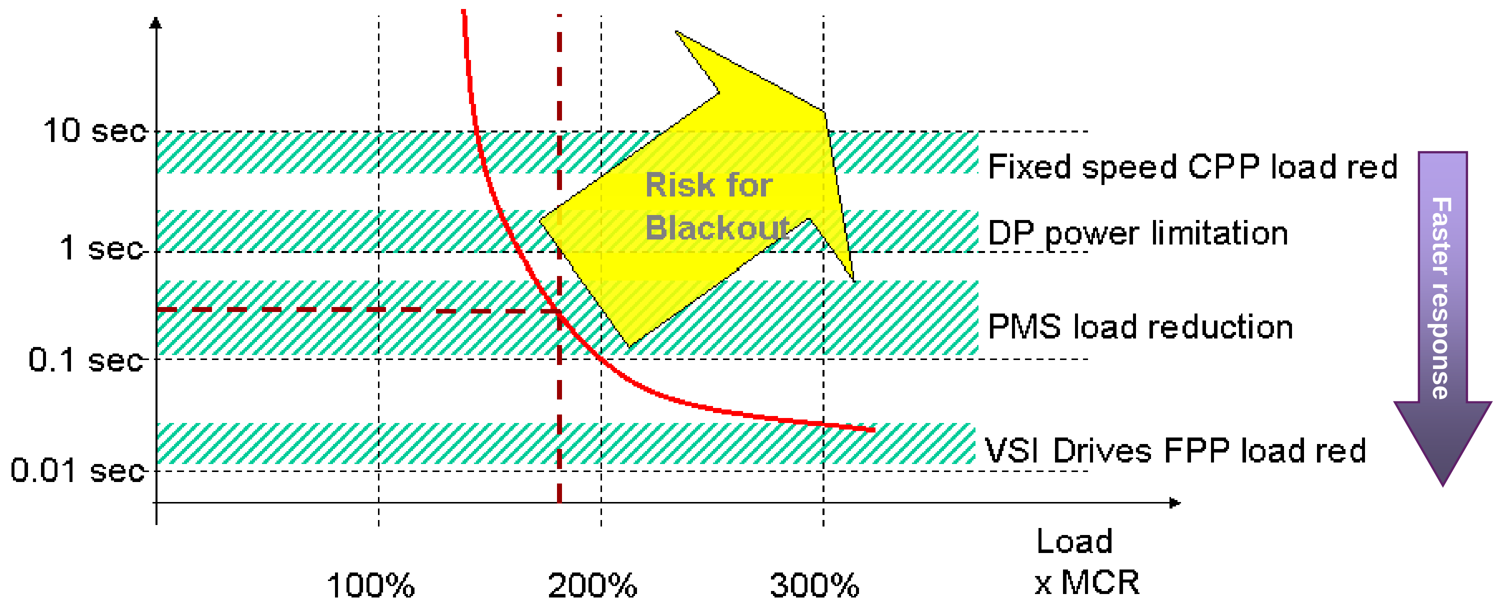
DG1: 11MW

DG2: 11MW

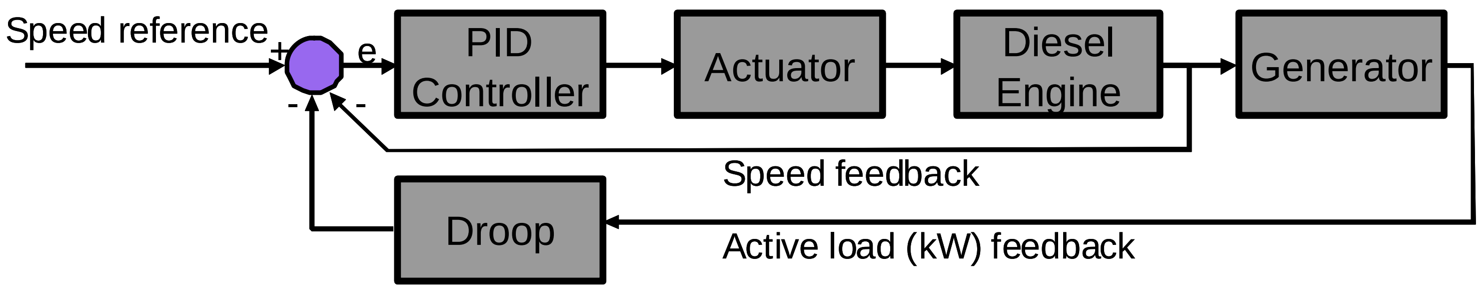
DG3: 11MW

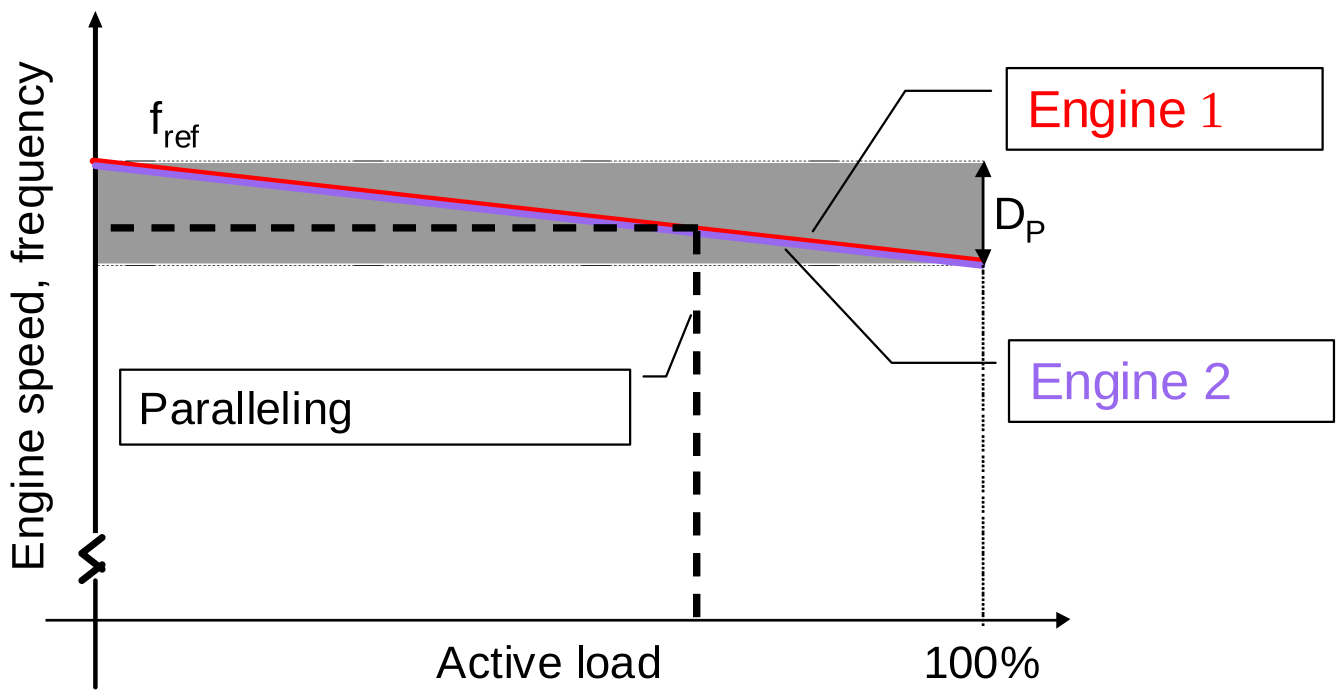
DG4: 5,5MW

Load Step Capacity of Diesel Engines
Load on Diesel Engine after Fault; Illustrative only

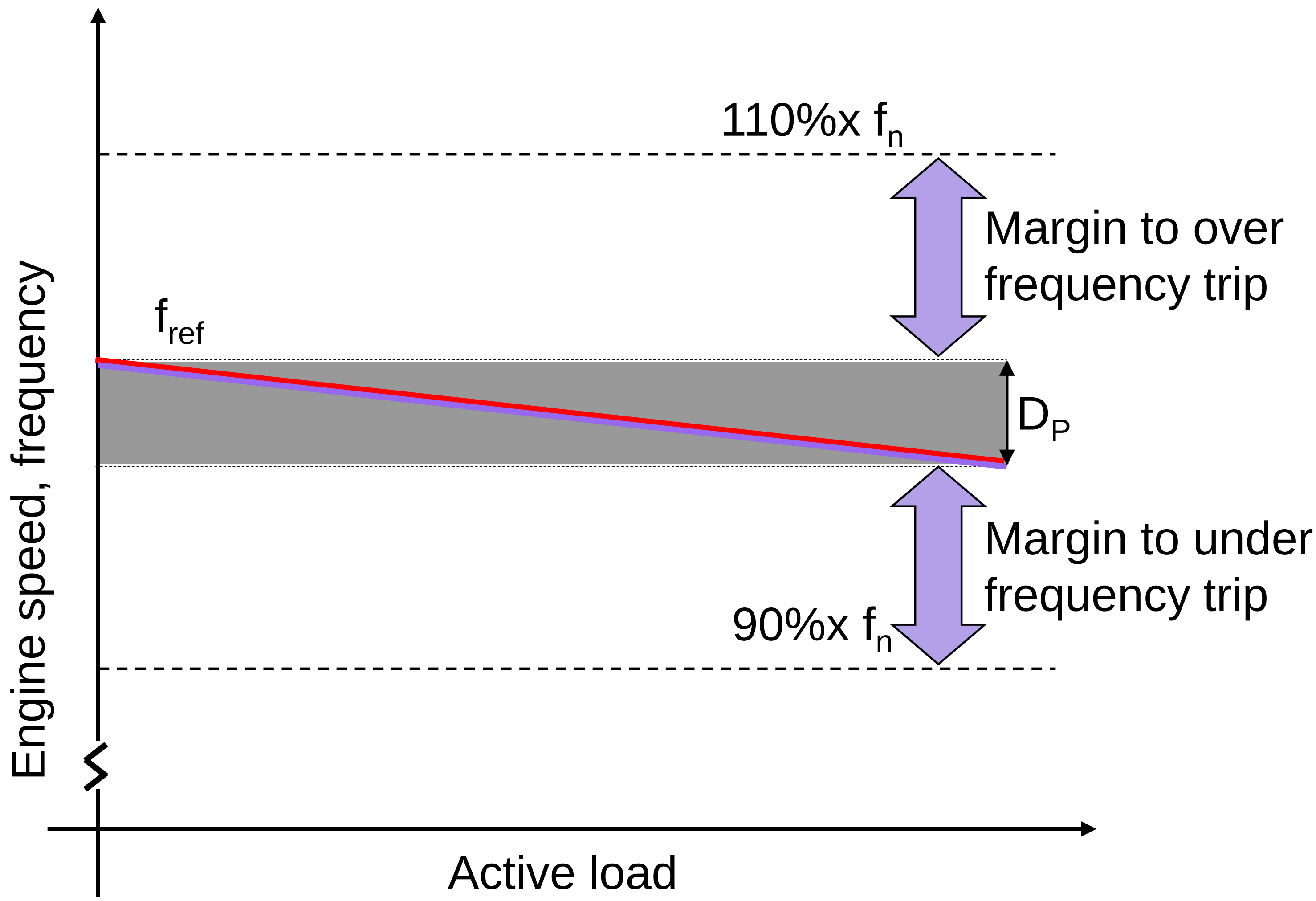


Frequency Margins are Influenced by Control Mode
E.g. Non-compensated Droop Mode





Frequency Margins are Influenced by Control Mode
Larger Frequency Variations



Failures of Diesel Engine or Generator Regulators
- AVR and Governors

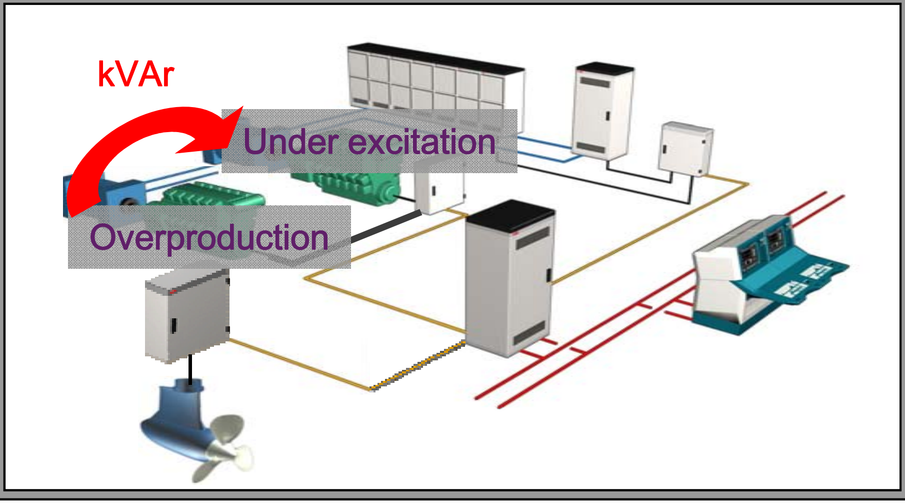
AVR Faults

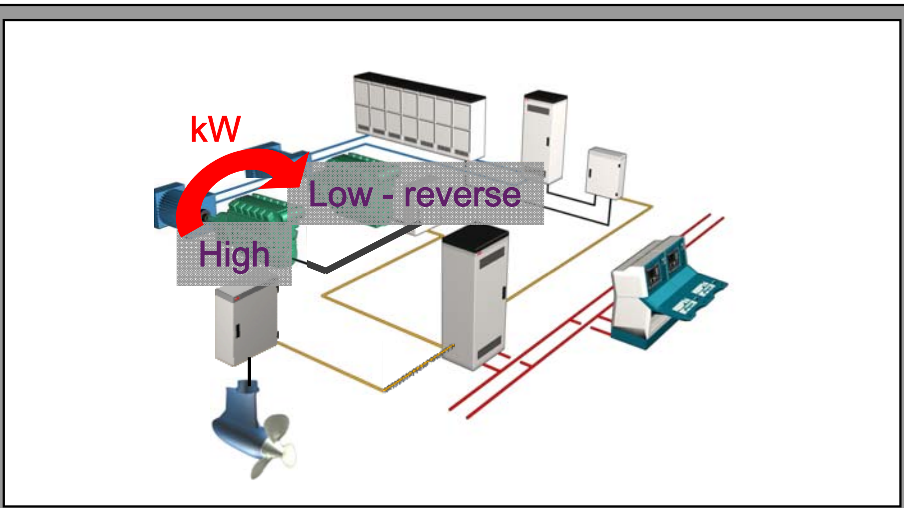
Under excitation

- Inductive (kVAr import)
- Under voltage
- Min kVAR

Over excitation

- Capacitive (kVAr) export
- Over voltage
- Max Amp





Governor faults

Failure to low fuel

- kW reduces (possible reverse)
- RPM may reduce

Failure to excessive fuel

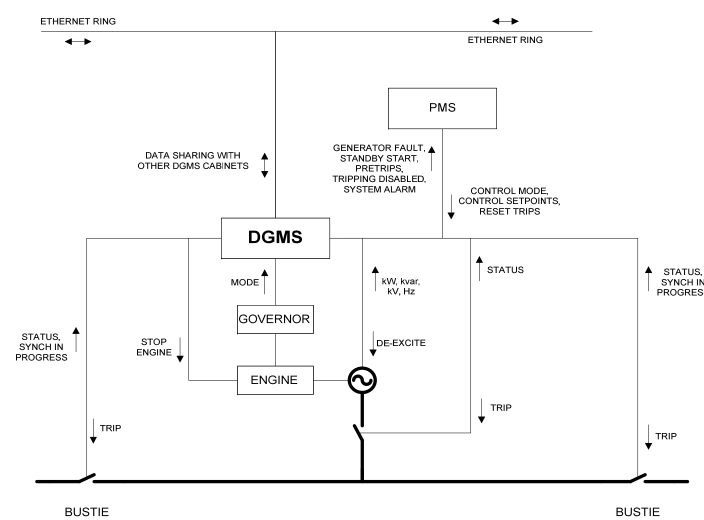
- kW increases
- RPM may increase

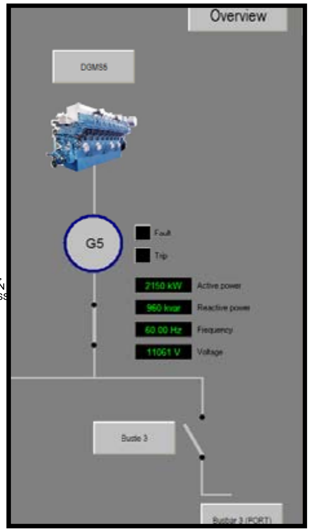
Rules and Regulations
Required Protection

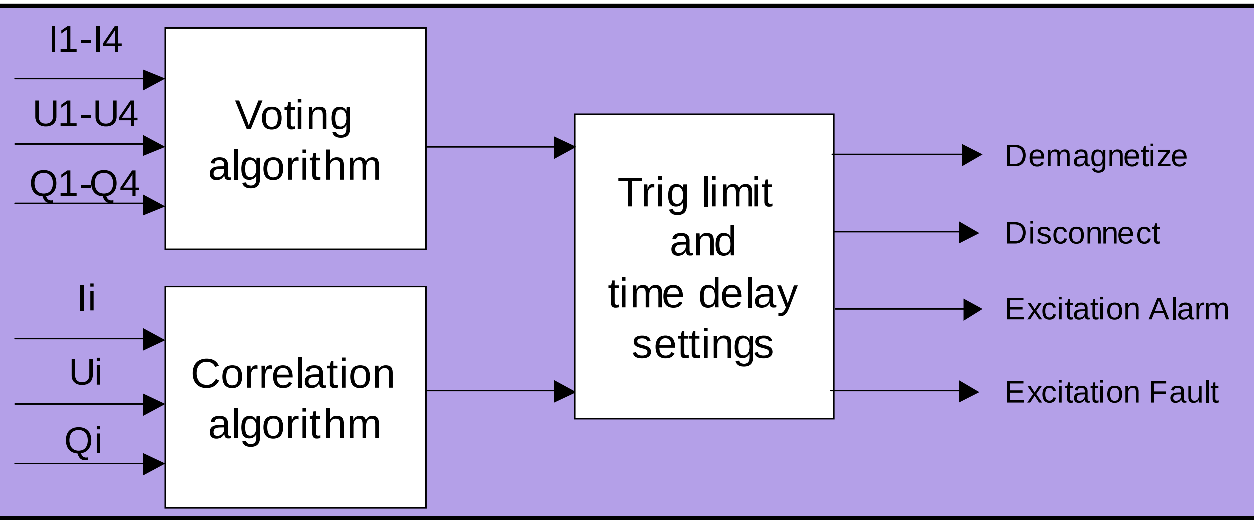
- In order to protect from instabilities in power plant and protect from damages, rules requirements are to protect against:
  - Under excitation
    - Protection against loss of excitation to generator
  - Reverse power
    - Protection against faults / loss of fuel to engine
- Risk:
  - Other fault modes and operating conditions may not be picked up by the required protection system, like:
    - Low load in network; and-
    - One engine fails to over-fueling
  - May lead to trip of healthy components, leaving the faulty on line, and eventually black-out (or partial black-out)
- Traditional mitigation of risk:
  - Operation with open bus ties
  - Careful coordination of the protection relay functions for the different failure modes and operating conditions
  - Thorough specification of the characteristics of the components to achieve correct selectivity; e.g. over current capacity of generators

DGMS
Diesel Engine and Generator Monitoring System

- PLC based system
- With supplementary protection system to those required by class:
  - Voting
  - Correlation
- System is in operation

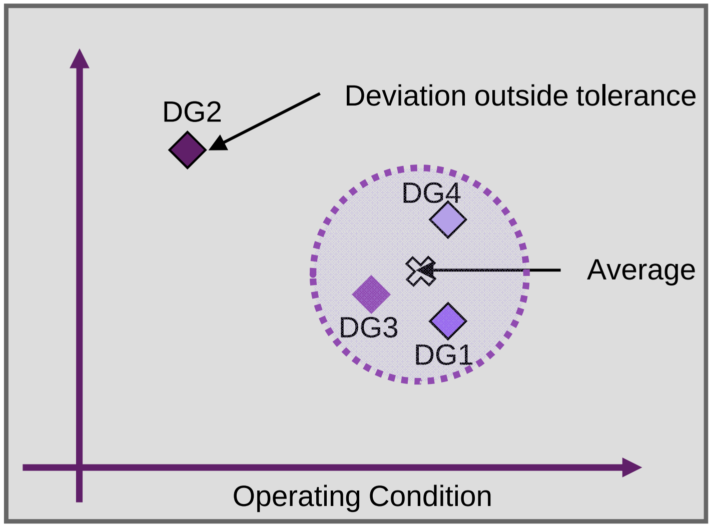


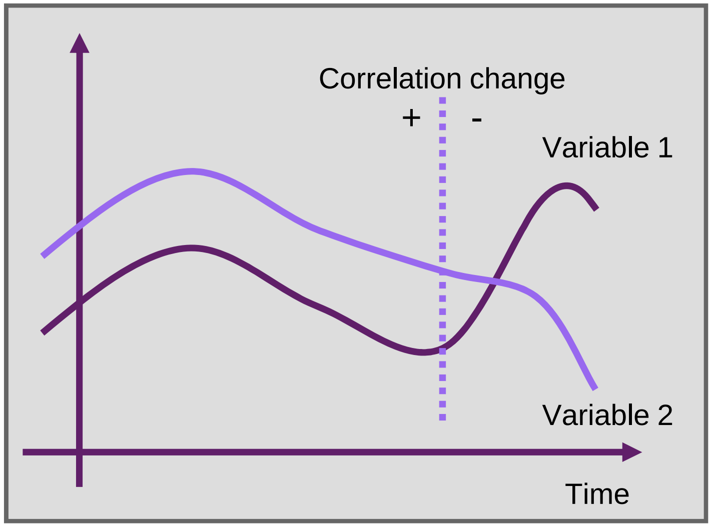




DGMS
Principles of Functionality

- Voting
  - Three or more gen-sets in parallel
  - Abnormal behavior (deviation from average) is detected by voting
  - Voting in common PLC
- Correlation
  - Relations between:
    Voltage – Reactive Power Output
    Frequency – Active Power Output
    are analyzed by correlation algorithm
  - Abnormal behavior (deviation from normal regulation) is detected
  - Independent monitoring





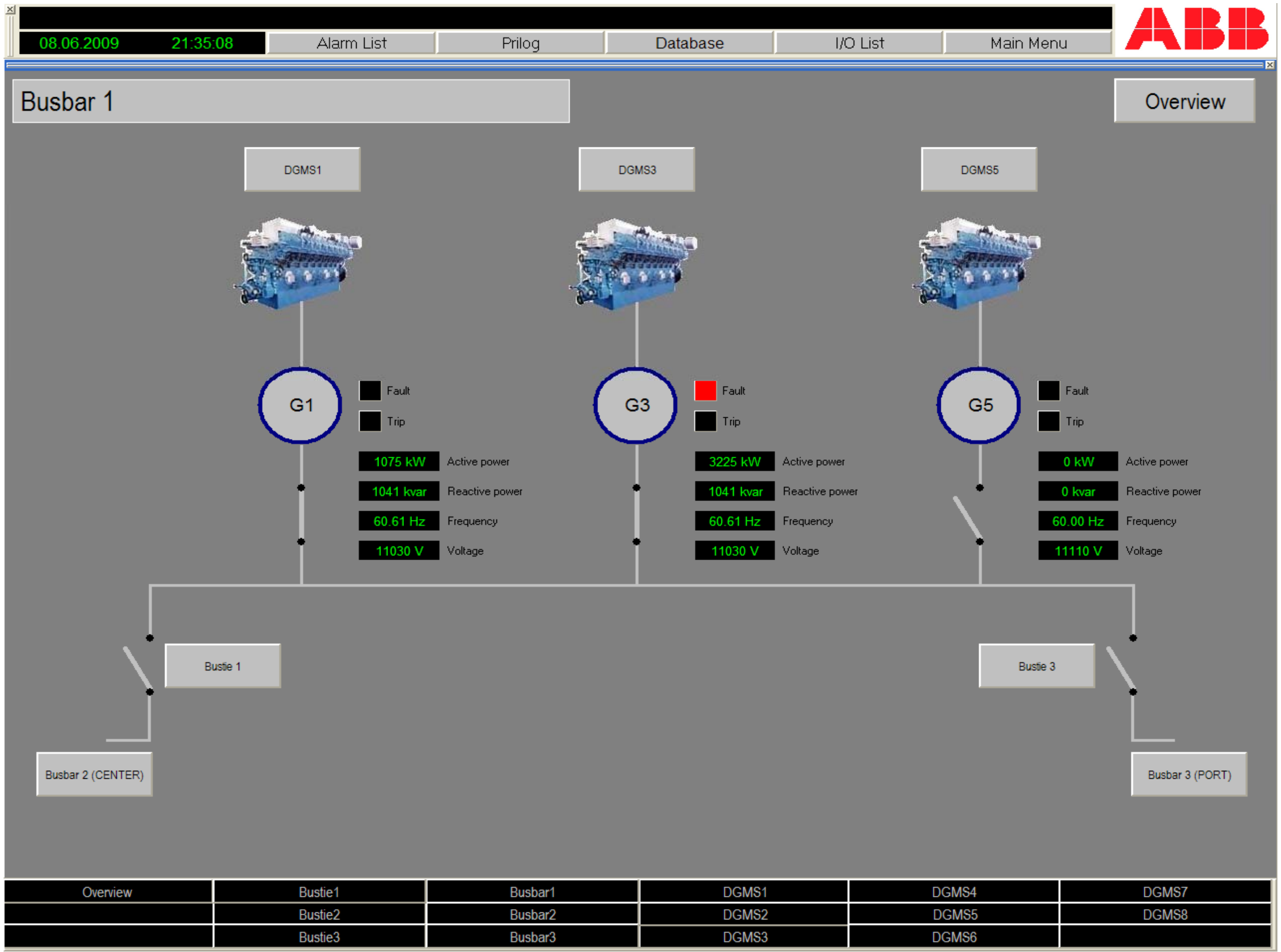
DGMS
System description

- PLC system based on ABB AC800 controllers and S800 IO
- Real time data collection via DEIF high performance transducers
- Data logging with playback function (separate cabinet)
- Time synchronization with ship clock or GPS
- Power supply and data network redundancy
- One DGMS cabinet per generator
- Stand alone cabinets for flexible mounting and easy retrofitting
- Available in isochronous, droop and base load mode
- Scalable for any power system configuration, up to 8 generators and 8 switchboards

Typical Protection Trips in DGMS
- Should Adapt to Installation Specific Requirements

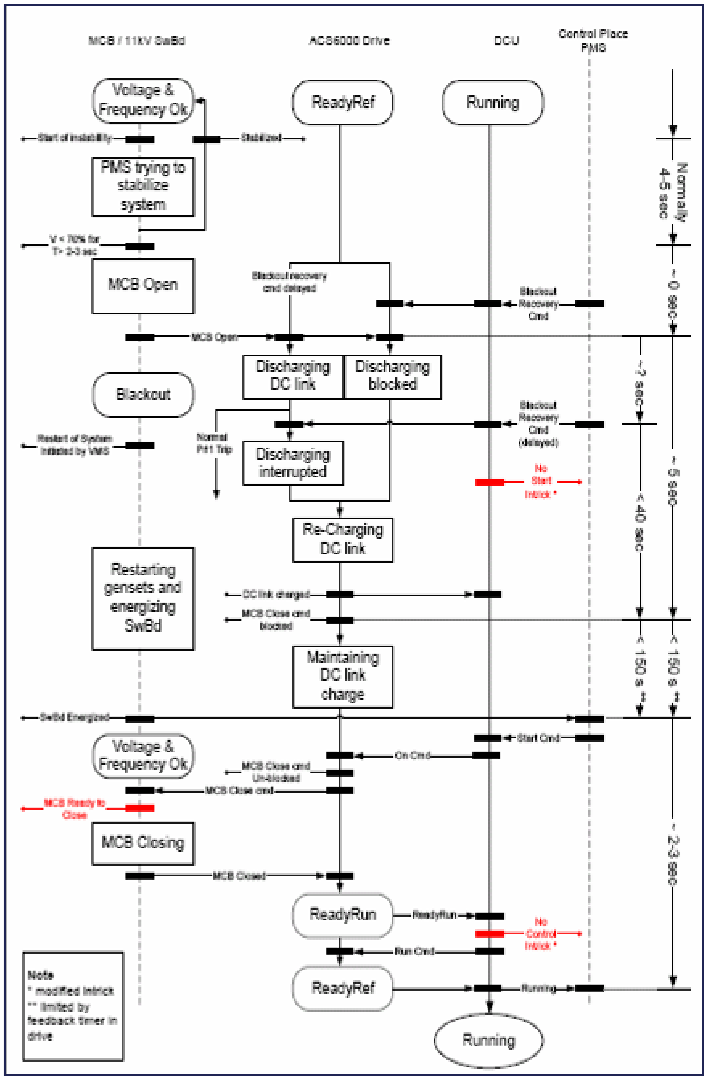
- Over-fuelling:
  - i. Stop engine and close fuel valve
  - ii. De-excite
  - iii. Open circuit breaker when active power falls to zero
- Over-excitation:
  - i. De-excite
  - ii. Open circuit breaker when reactive power falls to zero
- Under-fuelling or reverse active power:
  - i. Open circuit breaker
- Under-excitation or reverse reactive power:
  - i. Open circuit breaker
- Over-speed when circuit breaker is open:
  - i. Stop engine and close fuel valve
- Over-voltage when circuit breaker is open:
  - i. De-excite

User Interface
Case: Over-fuelling DG3 failed to 75% load

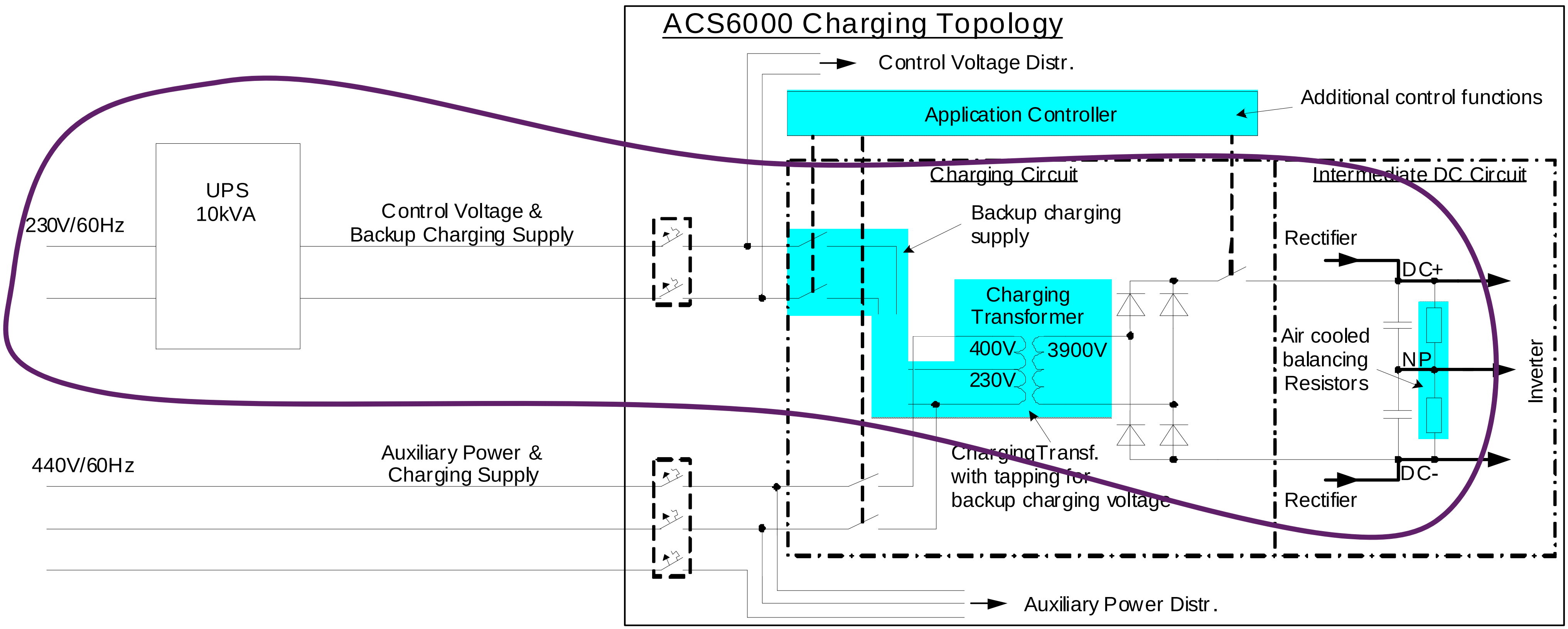


Fast Recovery after Blackout
FRAB

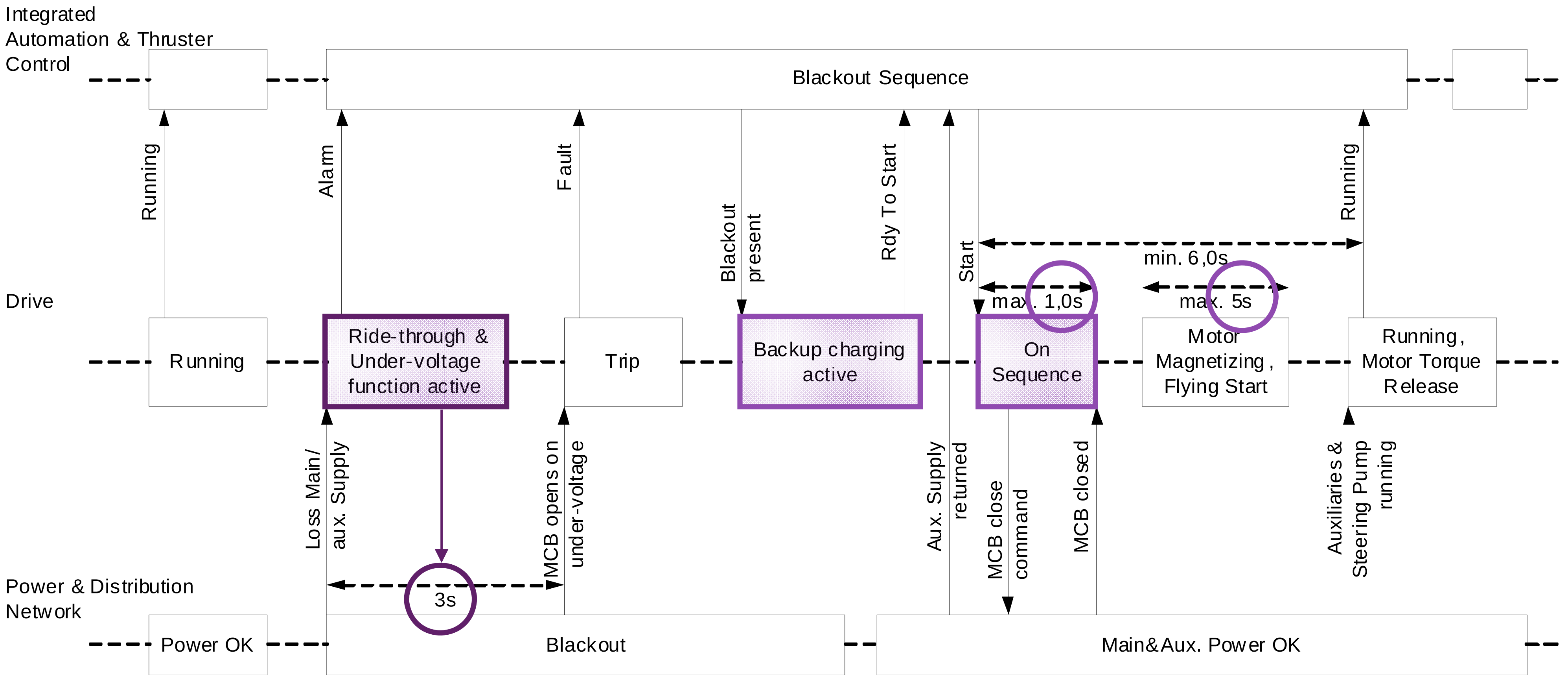
- Restoration sequence normally controlled by the automation system (ICMS)
  1. Starting engines
  2. Synch and connect generators
  3. Close bus ties (opt.)
  4. Close LV transformer feeders
  5. Start-up auxiliaries
  6. Start-up thruster drives
- Optimizing sequence alone, can cut restoration time substantially
- Restoration time may further be reduced by system design
- Simplicity and lower complexity to ensure reliable and robust restoration



Battery Backup
Maintain DC-link Voltage during Blackout



Critical Review of Restoration Sequence
Reduce Restoration Time



FRAB
ACS6000 Blackout Restart Sequence

- Blackout/power interruption shorter than 3s, covered by Ride-Through and under-voltage function in drive, no restart required
- Blackout/power interruption longer than 3s, restart time after power restored in the network appr. 6s for typical drillship application -highly depending on the rotor time constant determining the motor magnetization time
- Auxiliary and steering pump is restarted simultaneously with the thruster converter and restart time assumed to be within the converter restart time (to be verified with IAS, thruster and auxiliary system supplier)

Optional:

- Thruster converter, auxiliary and steering restart is autonomous controlled in the Drive Control Unit (DCU)

Summary

- Since 4th generation rigs, power plant reliability is improved
  - Variable speed thruster drives
  - Fast power reduction
  - More sophisticated and robust protection relays
- Yet room for improvements
  - Blackout prevention
    - Build in functionality in DP, PMS, and thruster drives
    - Essential to coordinate and functionally integrate
    - Diesel Engine and Generator Monitoring Systems
  - Blackout restart time
    - Can be reduced by additional components
    - Must be evaluated case by case, as increased complexity inevitable gives more failure modes
    - Must be robust to ensure reliable restoration

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