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DYNAMIC POSITIONING CONFERENCE
October 14-15, 2014

POWER/THRUSTERS

New Enhanced Safety Power Plant Solutions for DP Vessels Operating in Closed Ring Configuration

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Siemens AS Drilling and Marine

New enhanced safety power plant solution for DP vessels operated in closed ring configuration

By Stig Olav Settemsdal, Espen Haugan, Ketil Aagesen and Bijan Zahedi
Siemens AS, Drilling & Marine

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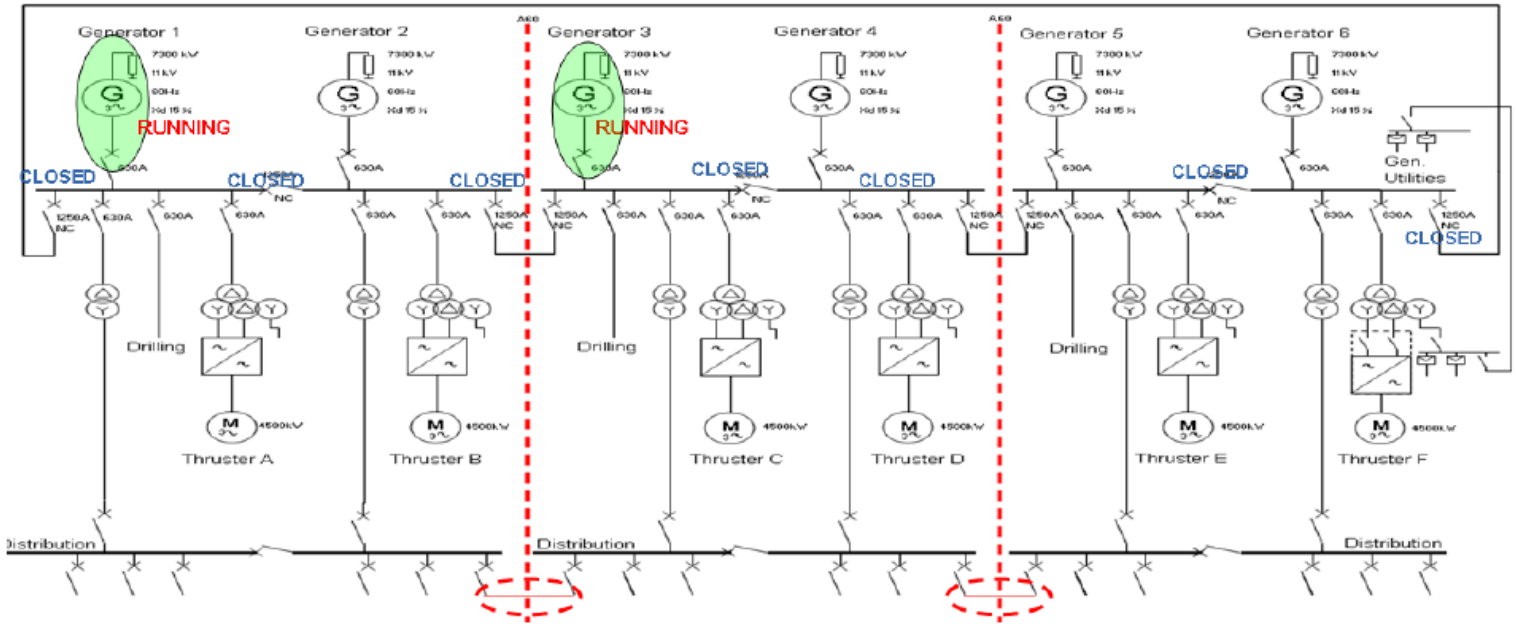
DP2/3 Closed Tie operation
- The background and The eight fundamentals

1) Avoid failures
   - High integrity switchboards
   - Insulated bus-bars and cable connections
   - Mechanical protection of cables
   - Interlocks for human errors
2) Autonomous system design – functional islands
3) In depth understanding of the power system behavior
   - Dynamic modeling, studies and relay plan
4) Avoid transients – pre-mag transformers and capacitors
5) Fast and selective disconnection if failure should happen
   - Including Fuel and Excitation failures
6) Back-up for hidden failures
7) Extended test program including fault ride through tests
8) Fast black-out recovery

1st generation closed ring solution



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

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The new enhanced safety power plant solution
- Simplified overview for a typical marine vessel and sizes

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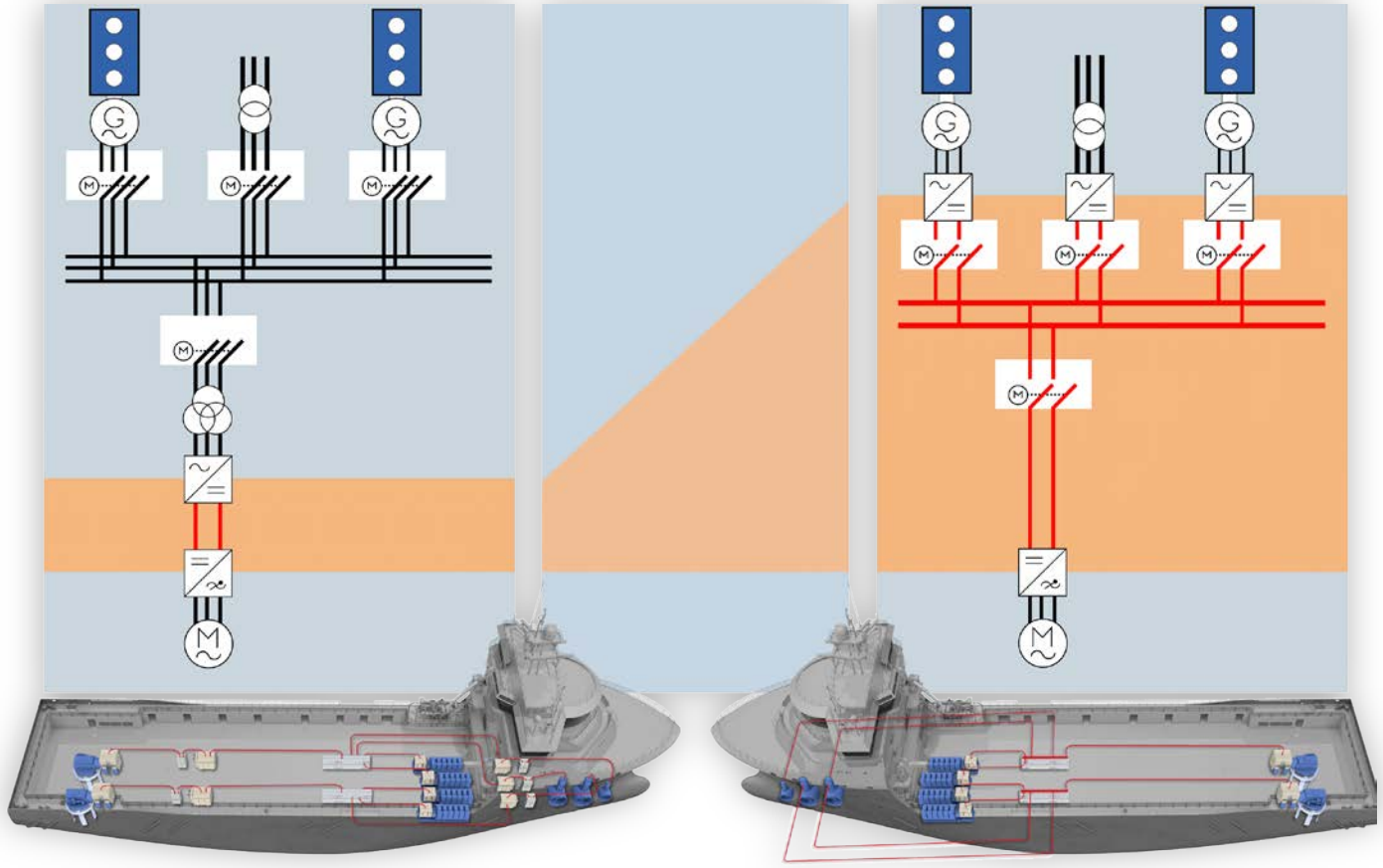
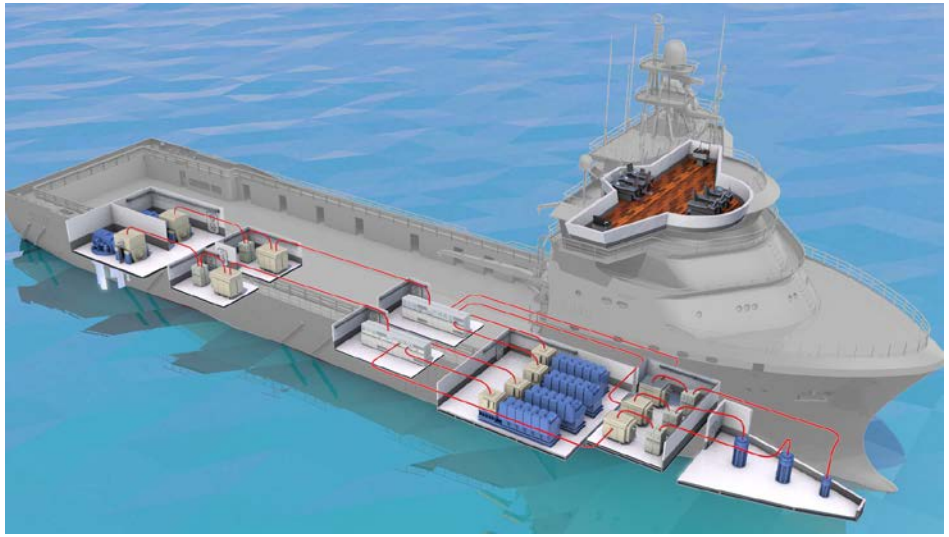


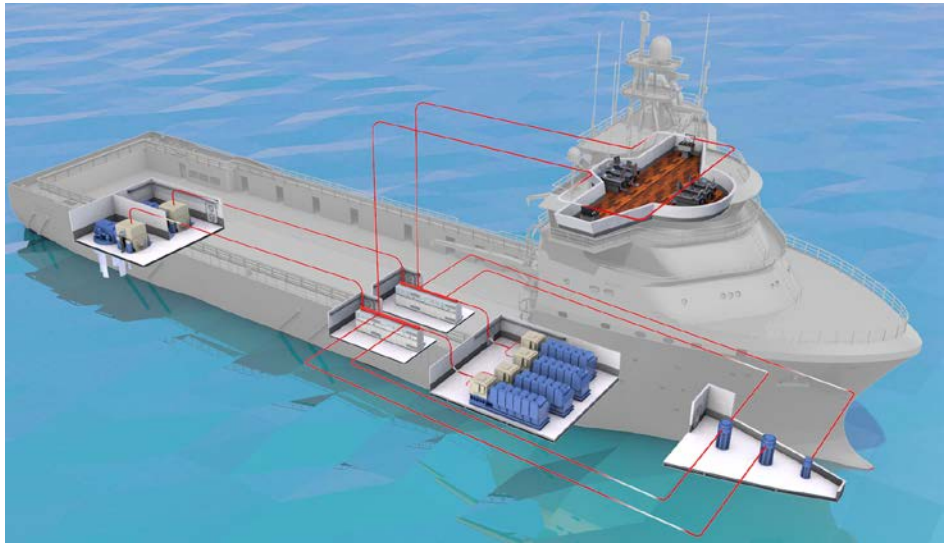
Old DEP

New DEP

Old DEP



New DEP



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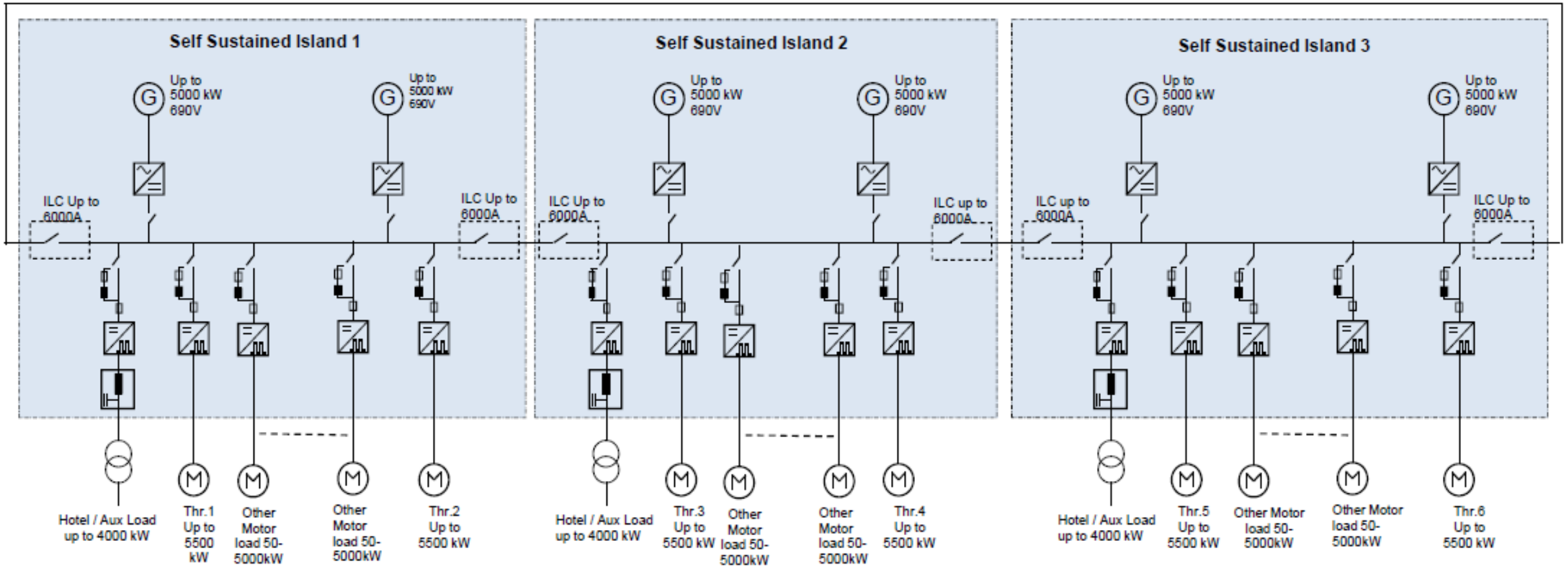
The new enhanced safety power plant solution
- Detailed representation of the solution



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The new enhanced safety power plant solution
New Technology

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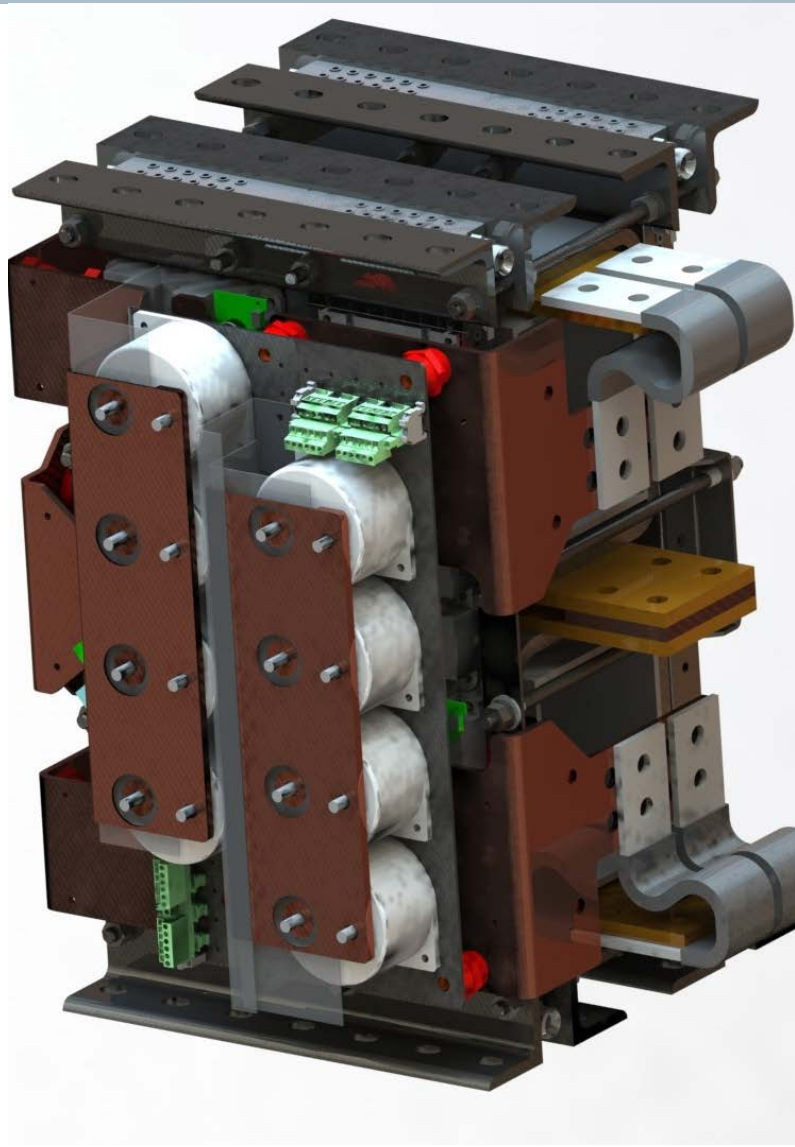
The solution is made with a range of new technologies

- **Generator, control and monitoring including load sharing**
- **Designed for variable engine speed and frequency (45-90Hz)**
- **Short circuit proof DC bus-tie (ILC) with very fast SC disconnect**
- **Energy storage technology for fault/blackout ride through**
- **Ship-net supply unit feeding clean power to LV distribution**
- **Seamless 50/60 Hz conversion for land supply or other tie-ins**



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The new enhanced safety power plant solution
New Technology

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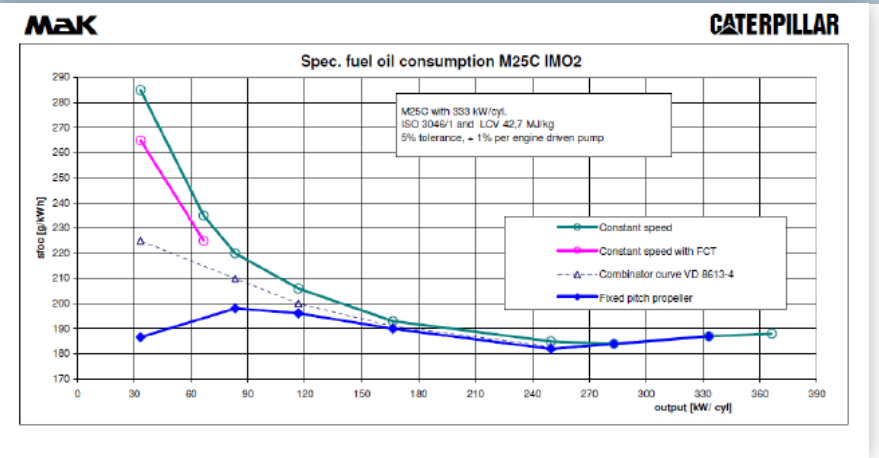
Power generation



- Diesel Engines and generator is designed for variable engine speed and frequency (45-90Hz)
- Diesel engines must be fitted with SCR's for optimized NOx emissions
- Generators designed with high Xd"
- Active load sharing by voltage regulation
- New type of protection based upon current measurements and control of the field of the generator. Disconnection of the field to disconnect the generator from the grid.
- Fuse less rectifiers are designed to survive the I_{SC} max from generator until field is disconnected.
- Live tests have been made to prove the concept.

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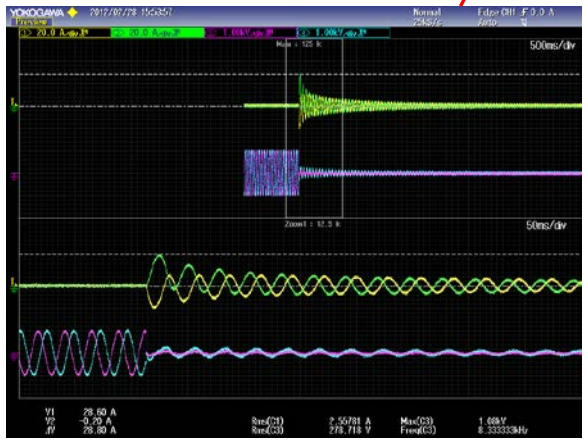
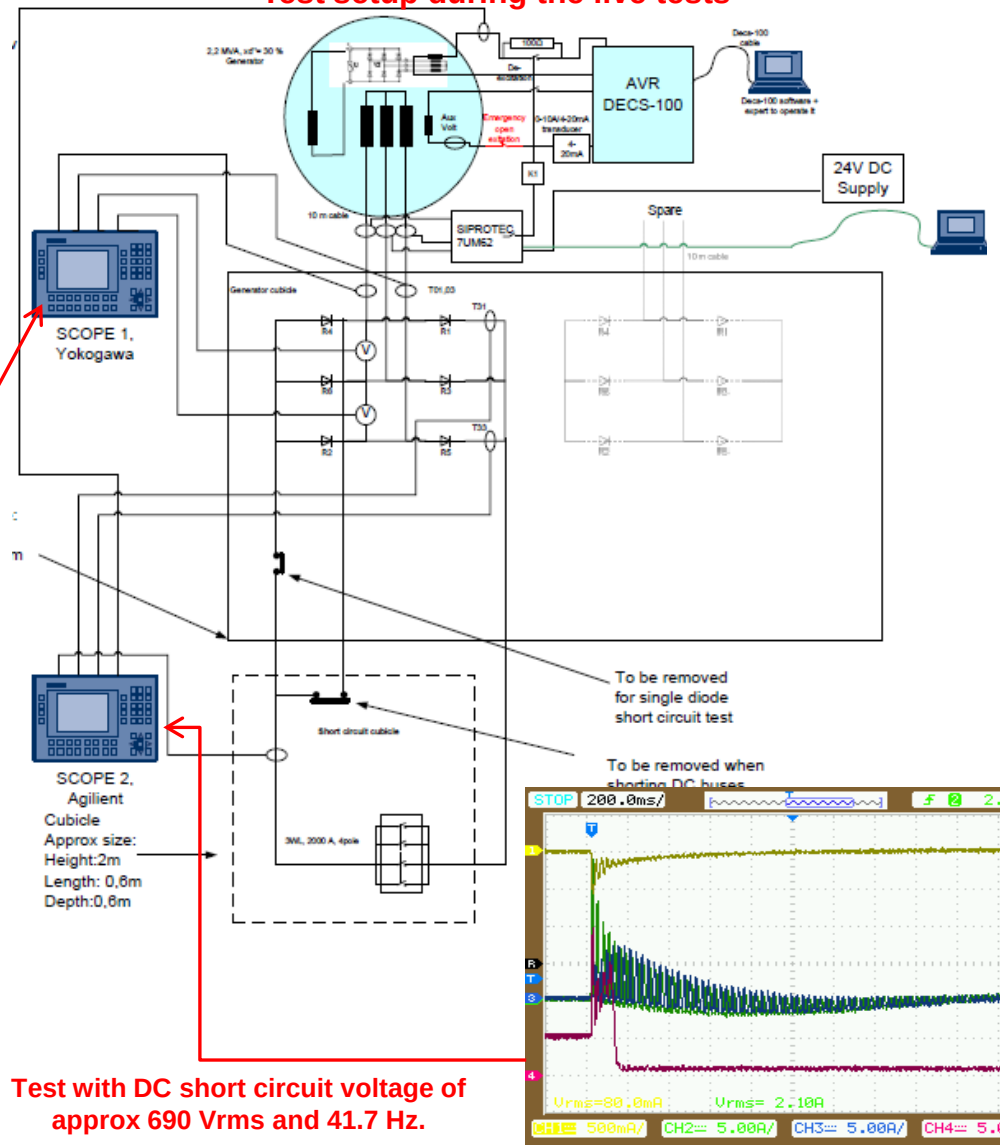
The new enhanced safety power plant solution
Power generation testing

The requirements defined for successful test:

- ✓ The diodes in the rectifier bridge should not be damaged during any of the short circuits tests.
- ✓ Mechanical torques in the machine and diesel during short circuit tests should not harm/destroy any of the mechanical parts/windings.
- ✓ Rectifier should not be damaged during the testing.
- ✓ The protection system shall disconnect the generator field fast enough to meet the above criteria's
- ✓ Protection system must be able to detect single diode fault and disconnect the faulty rectifier.



Test setup during the live tests



Test with DC short circuit voltage of approx 690 Vrms and 41.7 Hz.

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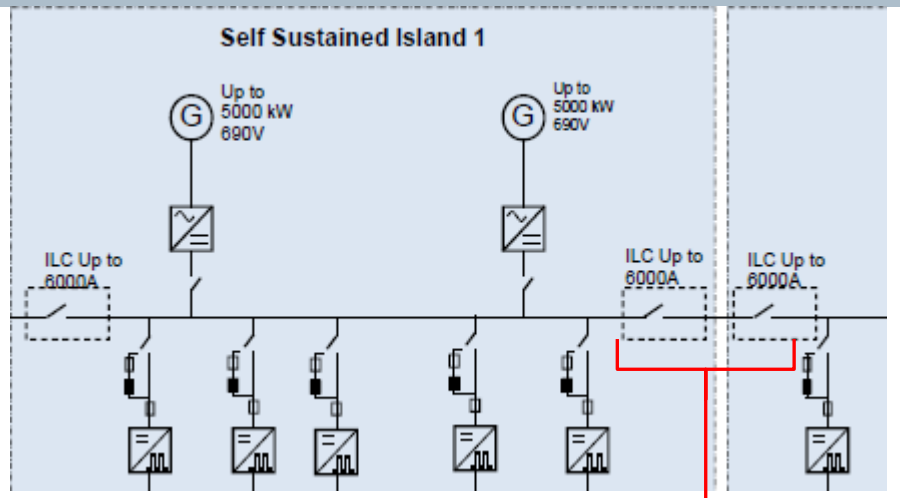
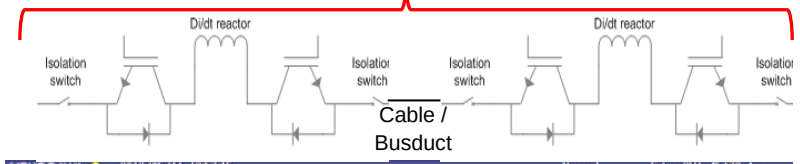
The new enhanced safety power plant solution
Power Distribution

- DC bus inside switchboard can be un isolated or isolated
- DC bus can be temperature monitored.
- All cabling is AC 690 V cables
- Connection between autonomous groups can be bus duct or cable
- Two bus-ties (ILC's) connects between each autonomous group for fault tolerance.
- ILC's trips short circuits @ 7000A within 10-50µS.
- ILC's can sync and reconnect two sections with voltage differences up to 50V DC.
- ILC's has 3 levels of safety built in.
- All loads are fed from inverters from the DC bus.
- One single motor drive can be up to 5,5 MW.
- Drives feeding clean power 60Hz to distribution with output filters and transformers. Size each feeder up to 4MW
- LV distributions can be connected with bus-ties and synced without involving gen-set control.





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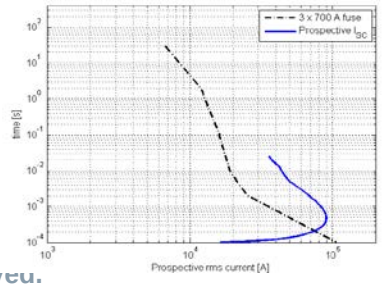
The new enhanced safety power plant solution
Power Distribution – Selectivity of fuses in the drive system

Sensitivity of fuses in the zone with min I_{SC}

The fuses are dimensioned so that they can clear any fault in their protection zone even with least possible energy level. Therefore, it is verified that each inverter fuse operates under minimum short circuit current conditions in their protection zone. These conditions hold when:

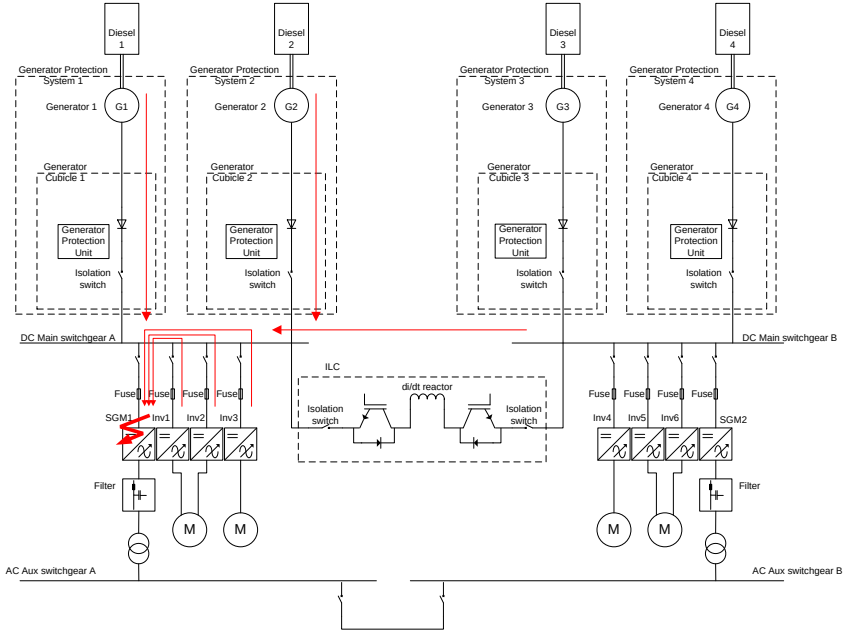
- Minimum number of generators and inverters are connected to the dc bus.
- The dc bus voltage is at lowest level within its range.
- The generator frequency is at its upper limit which creates largest sub-transient reactance
- illustrates that the sensitivity of the fuse of SGM1 is sufficient to interrupt a minimum short circuit fault in its protection zone. In this figure, the minimum prospective short circuit current is compared with the time-current pre-arc characteristic of the fuse. It can be seen that the fuse would start to melt in around 0.2 ms after the fault occurs.



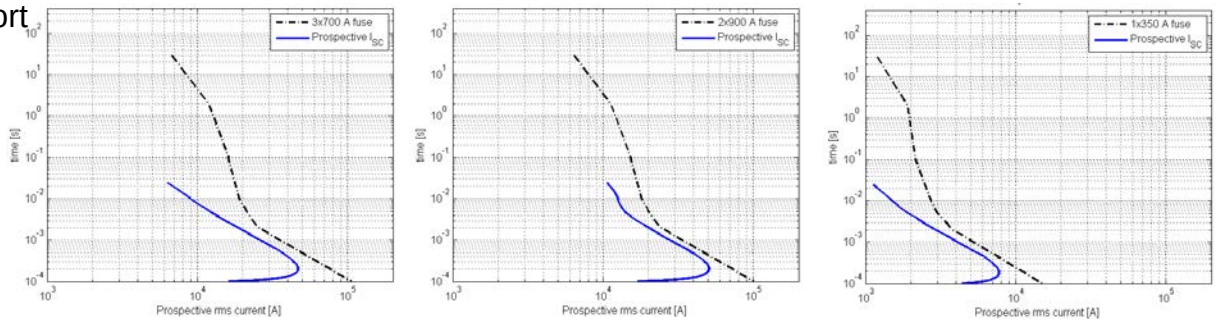
Selective operation of the fuses outside their zone.

In addition to the sensitivity requirements, the selectivity among different fuses is of great importance. This means that none of the fuses react to a fault out of their protection zones, even if the fault is of maximum possible energy. These conditions hold when:

- Maximum number of generators and inverters are connected to the dc bus.
- The dc bus voltage is at highest level within its range.
- The generator frequency is at its lower limit which creates smallest sub-transient reactance



None of the fuses of Inverters Inv1, Inv2, and Inv3 operates if a short circuit with maximum energy occurs in protection zone of SGM1 fuse or on the dc distribution bus.



Short circuit prospective (RMS) currents of inverters compared to their fuse pre-arc curves.
(From left to right: Inv1, Inv2, and Inv3)

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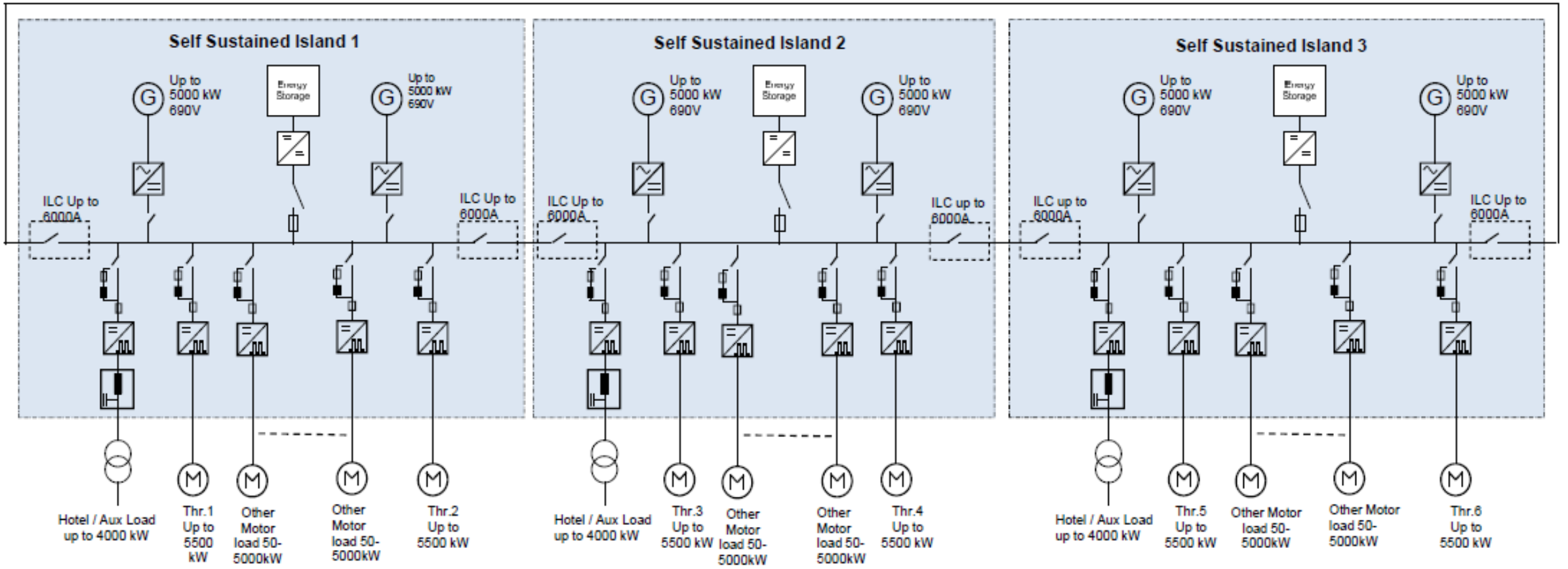
The new enhanced safety power plant solution
- Detailed representation of the solution including energy storage



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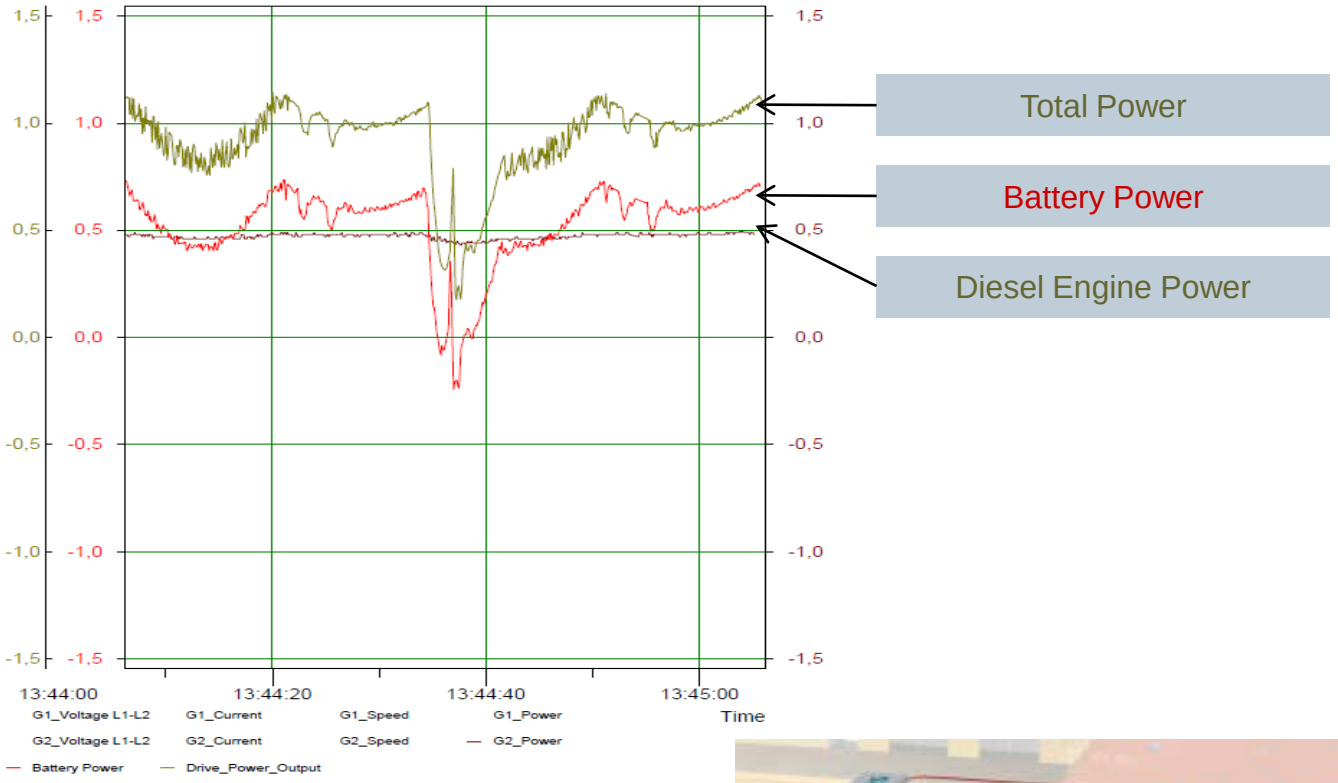
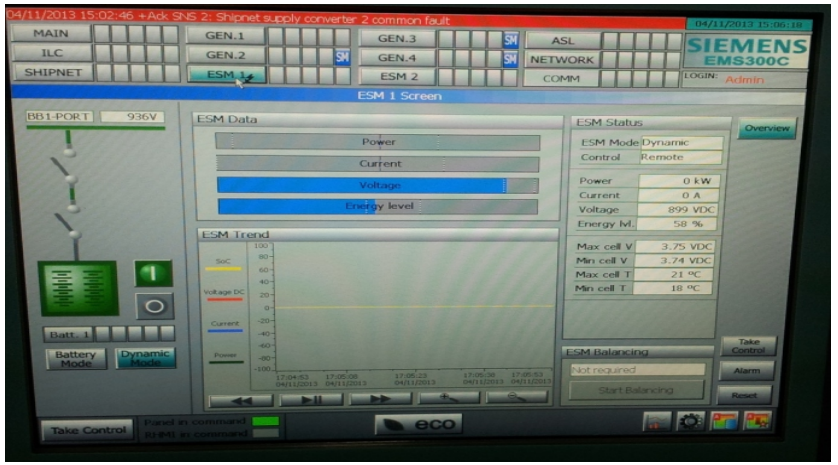
The new enhanced safety power plant solution
Energy Storage Module functions – Load levelling

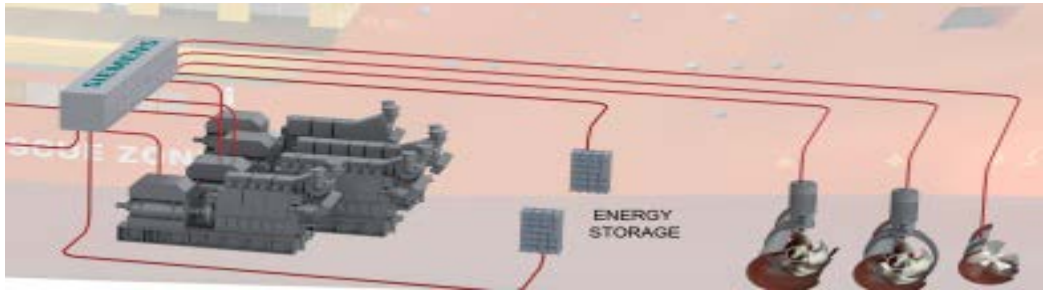


Total Power

Battery Power

Diesel Engine Power





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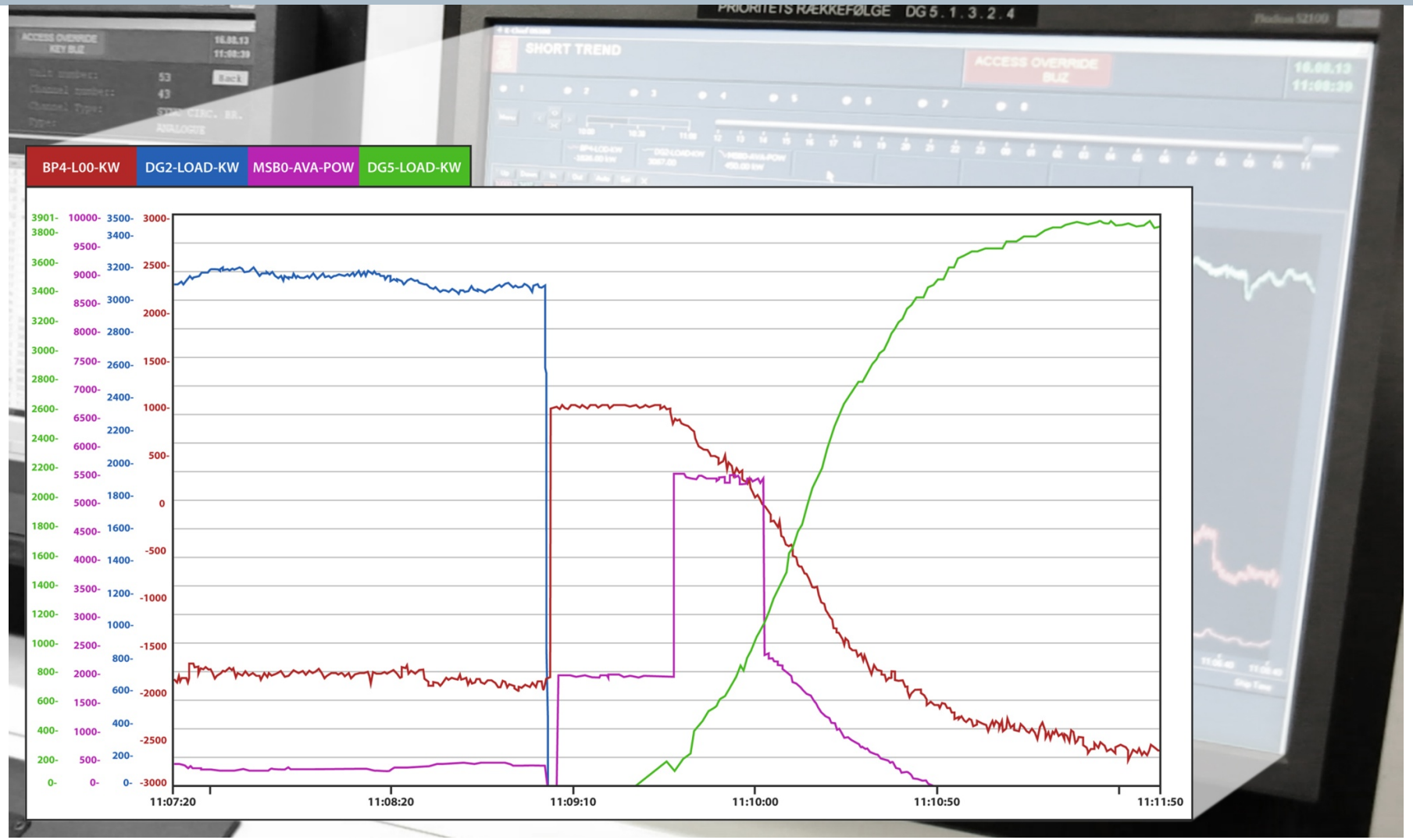
The new enhanced safety power plant solution
Energy Storage Module functions - blackout ride through



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The new enhanced safety power plant solution
Revisiting the fundamentals for the new system

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- ✓ Avoid failures
  - ➢ Low energy power system
  - ➢ Components can survive SC failures like generators, rectifiers and inverters (exept internal fault)
  - ➢ Ultra fast failure disconnect between redundancy groups
  - ➢ Isolated temp monitored bus bars
- ✓ Autonomous system design – functional islands are not compromised with the new system
- ✓ In depth understanding of the power system behavior
  - ➢ Dynamic modeling, studies are still essential.
- ✓ Avoid transients not necessary
- ✓ Fast and selective disconnection if failure should happen
  - ➢ Trip of engines by excitation disconnect
  - ➢ Ultra fast failure disconnect
- ✓ Back-up for hidden failures only necessary in bus-ties (ILC's) due to low energy in the system
- ✓ Extended test program including fault ride through tests done during FAT
- ✓ Fast black-out recovery due to no need for synchronizing and ACB connection

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The new enhanced safety power plant solution
Conclusion

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The fundamental principle in a safe and reliable closed ring operated power plant is to segregate the station keeping equipment into self-sustained autonomous groups. A single failure also considering hidden failures shall not reduce the capability of the plant to less than the design intent. The protection system must be made to comply with these fundamentals.
The new solution discussed in this paper can be said to comply in a better way than an AC closed ring solution due to the following:

- ✓ The ILC bus ties segregating the power sections are tripping a short circuit fault in 10-50µS, the trip level is set at 7000A DC and it is proven that it trips on the rising SC flank.
- ✓ This ultra fast tripping ensures that the other sections are unaffected by the short circuit fault.
- ✓ Fault ride through testing of the system to prove this capability is done in the test field during FAT. This type of testing is not destructive in a LV power plant when designed as described.
- ✓ This solution improves fuel & emissions savings substantially compared with most other existing AC power grid solutions due to the variable frequency operation of the diesel engines.
- ✓ This solution combined with suitable sized energy storages can further enhance operation, safety, maintenance, fuel efficiency and emissions.
- ✓ MW capacity energy storages installed in this solution can further reduce (remove) the risk of blackouts and assist with extended recovery time (1 - 60 minutes) to enable safe restart of diesel engines.

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We are happy to answer your questions……