Dynamic Positioning Committee

Marine Technology Society

DP INNOVATION

A Novel Solution to Common Mode Failures in DP Class 2 Power Plant

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A Novel Solution to Common Mode Failures in DP Class 2 Power Plant

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Introduction

Advanced Generator Protection

Advanced Thruster Control and Protection

Propulsion Redundancy for DP

- DP Class 2 vessels must be able to maintain position and heading following the failure of any active component.
- The connections between redundant elements such as generators and thrusters present challenges for designers of fault tolerant systems.
- Fault tolerance is to be proven by FMEA and trials.

Common Mode Failures (CMF)

- A failure in which several apparently separate and redundant elements react adversely to a fault in one redundant element or elsewhere in the plant.
- This can lead to blackout and/or loss of position.

Typical Power System CMF

Primary fault conditions:

- Over and under frequency
- Over and under voltage
- Over load – rating of engine exceeded
- Over current – rating of alternator exceeded

Secondary fault conditions:

- Severe active power sharing imbalance
- Severe reactive power sharing imbalance
- Excessive regeneration of power

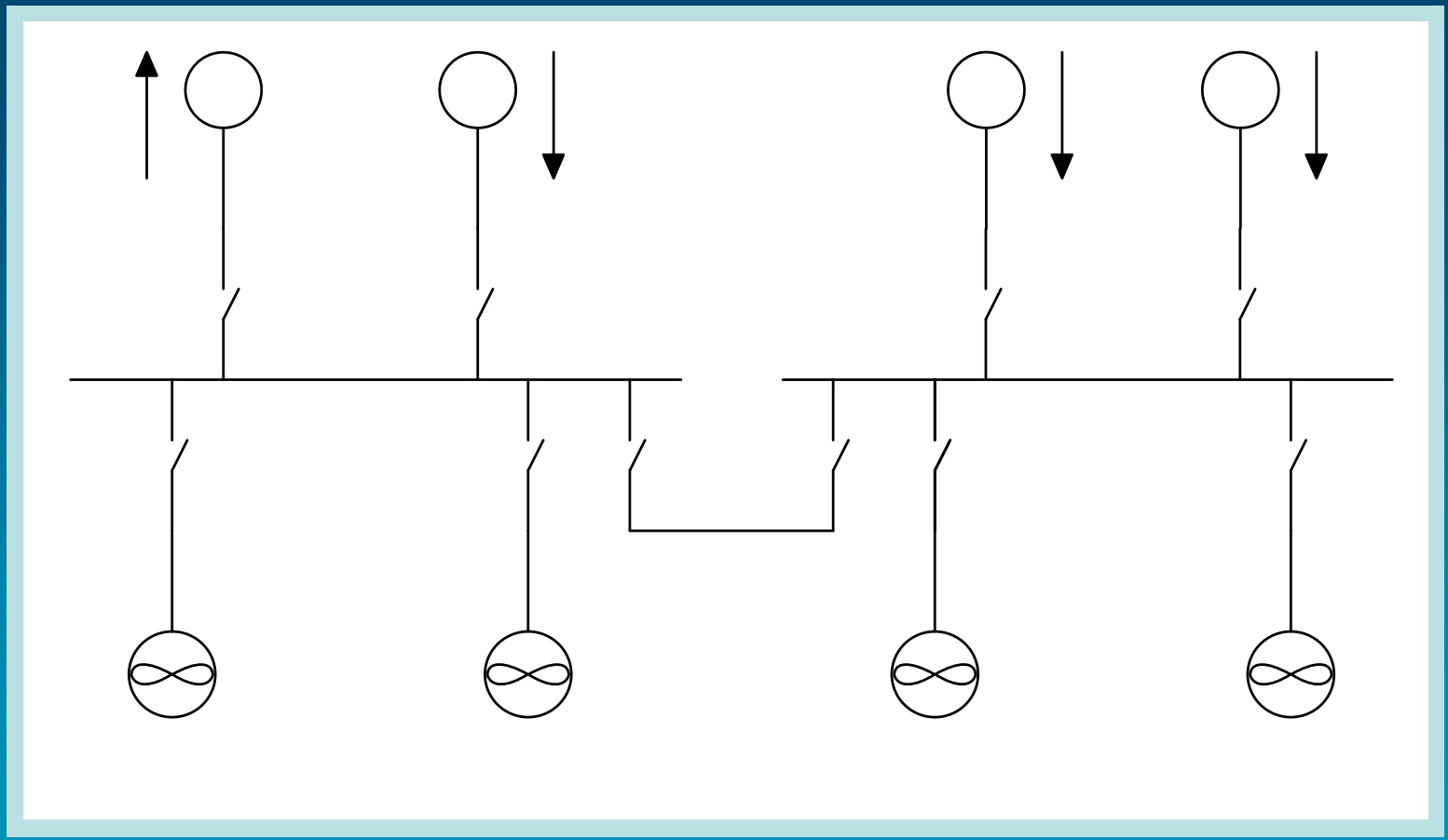
Failure Scenarios

- There are two failure scenarios in parallel generator operation which pose particular challenges:

- Severe load sharing imbalance between generators leading to multiple generators being tripped by their reverse power protection.

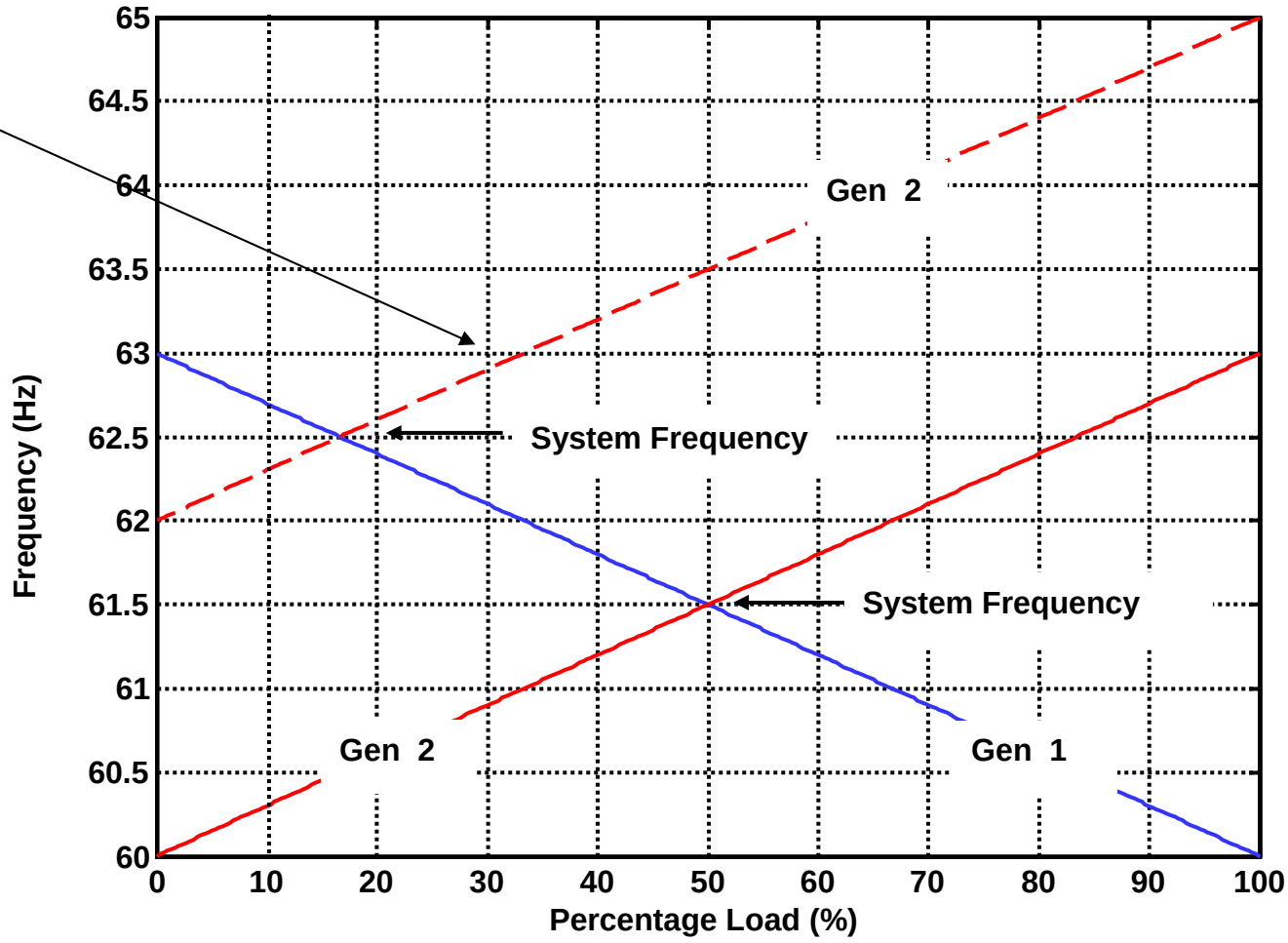
- Severe reactive power sharing imbalance between generators leading to multiple generators tripping on their field failure protection.

Load sharing imbalance leading to blackout



Load Sharing by Speed Droop

PMS can adjust the speed (frequency) offset of this line to achieve equal load sharing. Can also be used for asymmetric load sharing. This speed / load characteristic may also change in gain and offset in response to a PMS or governor failure.



Conditions

- Conditions must be right for these AVR and governor failures to succeed in defeating the redundancy concept.
- In general, the total kW and/or kVAr demand must be less than the rating (capability) of the faulty generator.

Was This Always a Problem?

- The first generation of diesel electric vessels used relatively small generators to power controllable pitch thrusters driven by large asynchronous motors.
- Some power systems can be inherently immune to these failures because:
  - Controllable pitch thrusters create a significant base load under all conditions
  - Asynchronous motors create a significant kVAr demand
  - Generators were small in relation to system base load

The Effects of New Technologies

The introduction of fixed pitch thrusters driven by variable speed drives and the demand for ever more powerful oil field construction vessels has created a situation where:

- Total system kW load can be relatively low in benign environmental conditions.
- kVAr demand is low because modern variable speed drives operate with a high power factor.
- Generators are large in relation to the base load in benign conditions - so a faulty set is capable of carrying the entire system kW and kVAr demand.

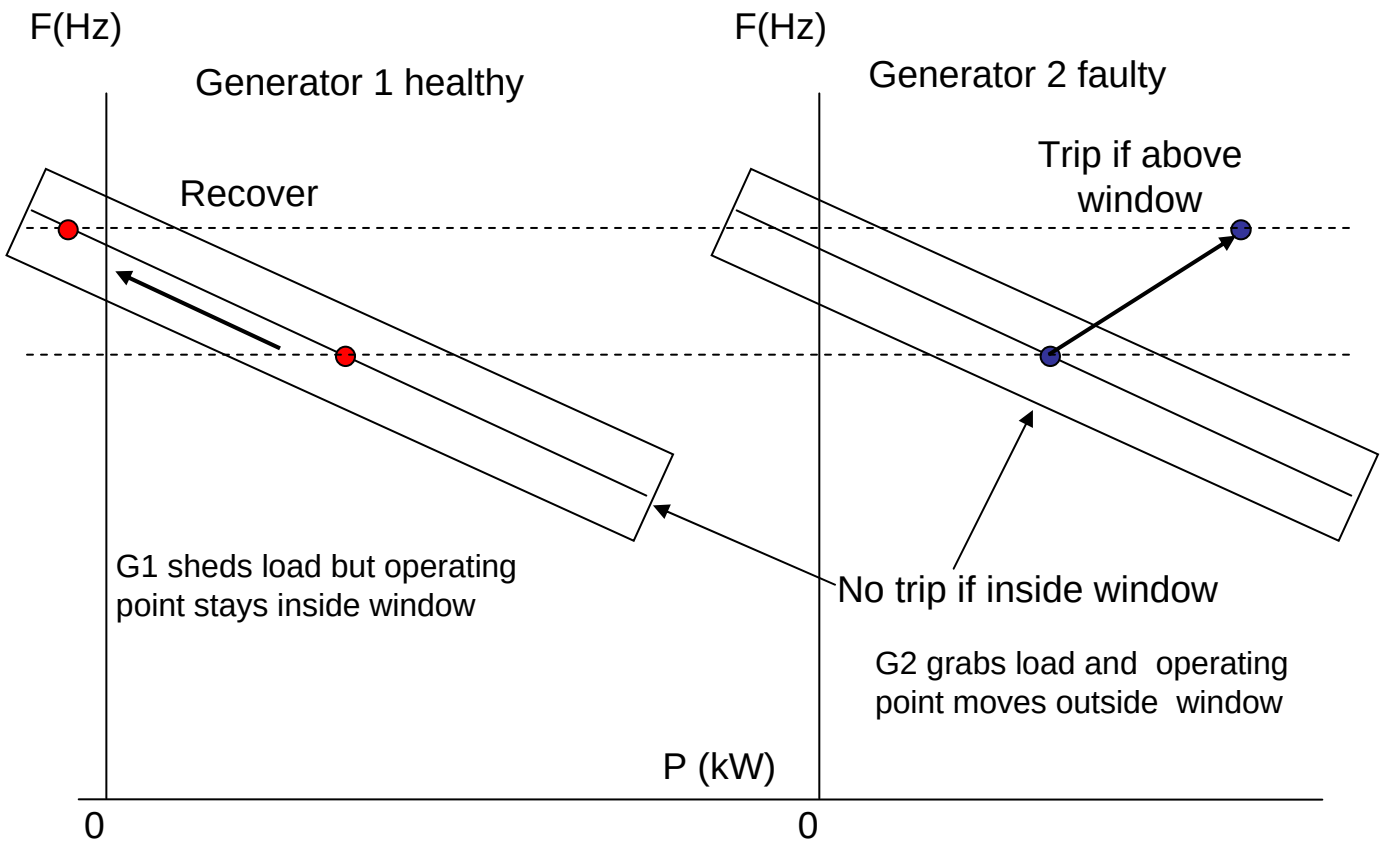
AGP

ADVANCED GENERATOR PROTECTION

Features of AGP

1. Can identify a faulty generator which has failed to excess fuel.
2. Can identify a faulty generator that has failed to over excitation.
3. Will open the bustie if the faulty generator fails to trip.
4. Will start all available generators
5. Has a range of other protection functions and acts as a backup to the traditional generator protection relay.
6. Each generator is monitored individually – no cross comparison or voting on which generator is faulty.
7. One protection system per generator with very few connections between generators for protection purposes so if the system itself fails it can only trip its own generator.
8. Plant must be run in uncorrected droop mode for kW and kVAr.
9. Several vessels now fitted with this protection - earliest dating back to 2006.
10. Fairly major switchboard control modification.
11. No history of spurious tripping.

How it Works


F(Hz)
Generator 1 healthy
Recover
G1 sheds load but operating point stays inside window
P (kW)
0
F(Hz)
Generator 2 faulty
Trip if above window
No trip if inside window
G2 grabs load and operating point moves outside window
0

Other Common Mode Failures

- Short circuit faults occurring anywhere in the main power distribution can cause severe dips in the system voltage.
- This voltage dip will be experienced by all power consumers.
- Consumers essential to DP must be able to ride through it without interruption.

Consumers at Risk of Interruption

- Variable speed drives for thrusters
- Motor starters for:
  - SW pumps
  - FW pumps
  - Hydraulic pumps
  - Ventilation fans
  - Compressors
- Any sensitive system not supplied from a UPS

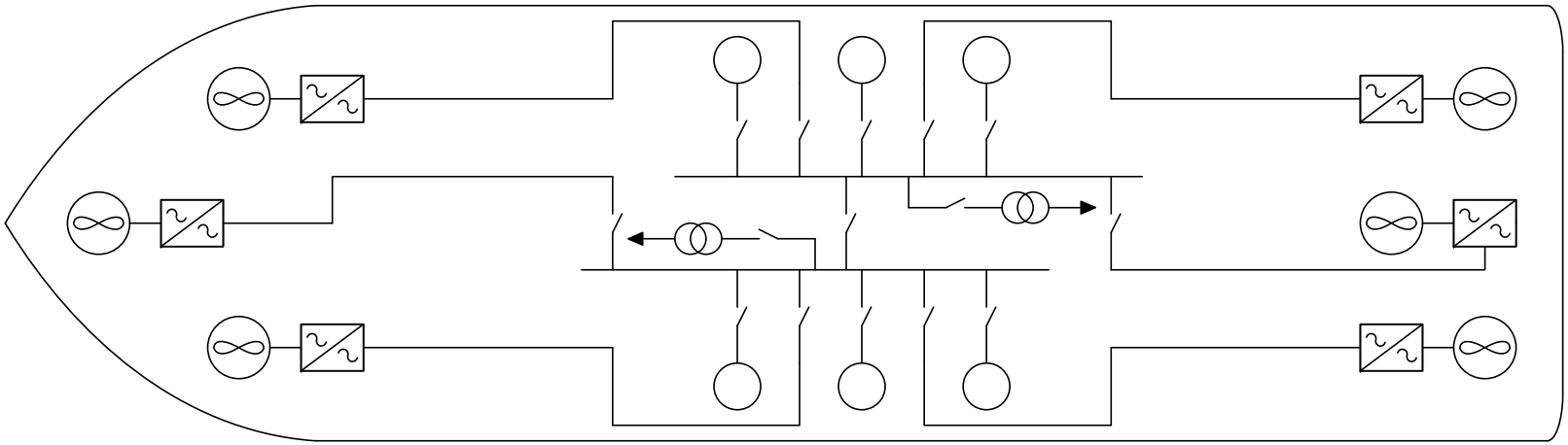
ATCP

Transocean

NOBLE DENTON

ADVANCED THRUSTER CONTROL AND PROTECTION INITIATIVE

Conventional
DP Class 2 Power Plant

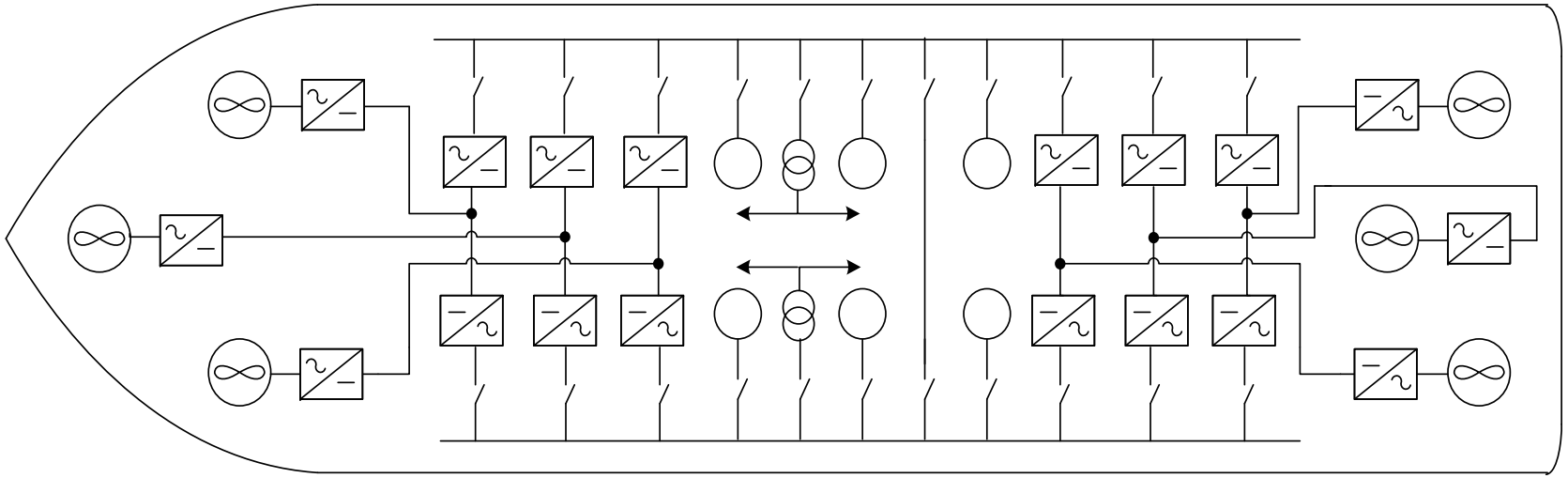


Worst Case Failure - Loss of three generators and three thrusters – Only one bow thruster available

Improvements

- Improved immunity to CMF - Reduce the number of failure modes that can lead to loss of one power system (AGP & Siplink)
- Reduce disturbance and delay associated with thruster connection (pre-charging & pre-magnetising from battery bank)
- Higher thruster availability following loss of one power system (dual supply)
- Autonomous blackout prevention by using power frequency to indicate plant loading (uncorrected droop mode)
- Rapid blackout recovery through decentralised control

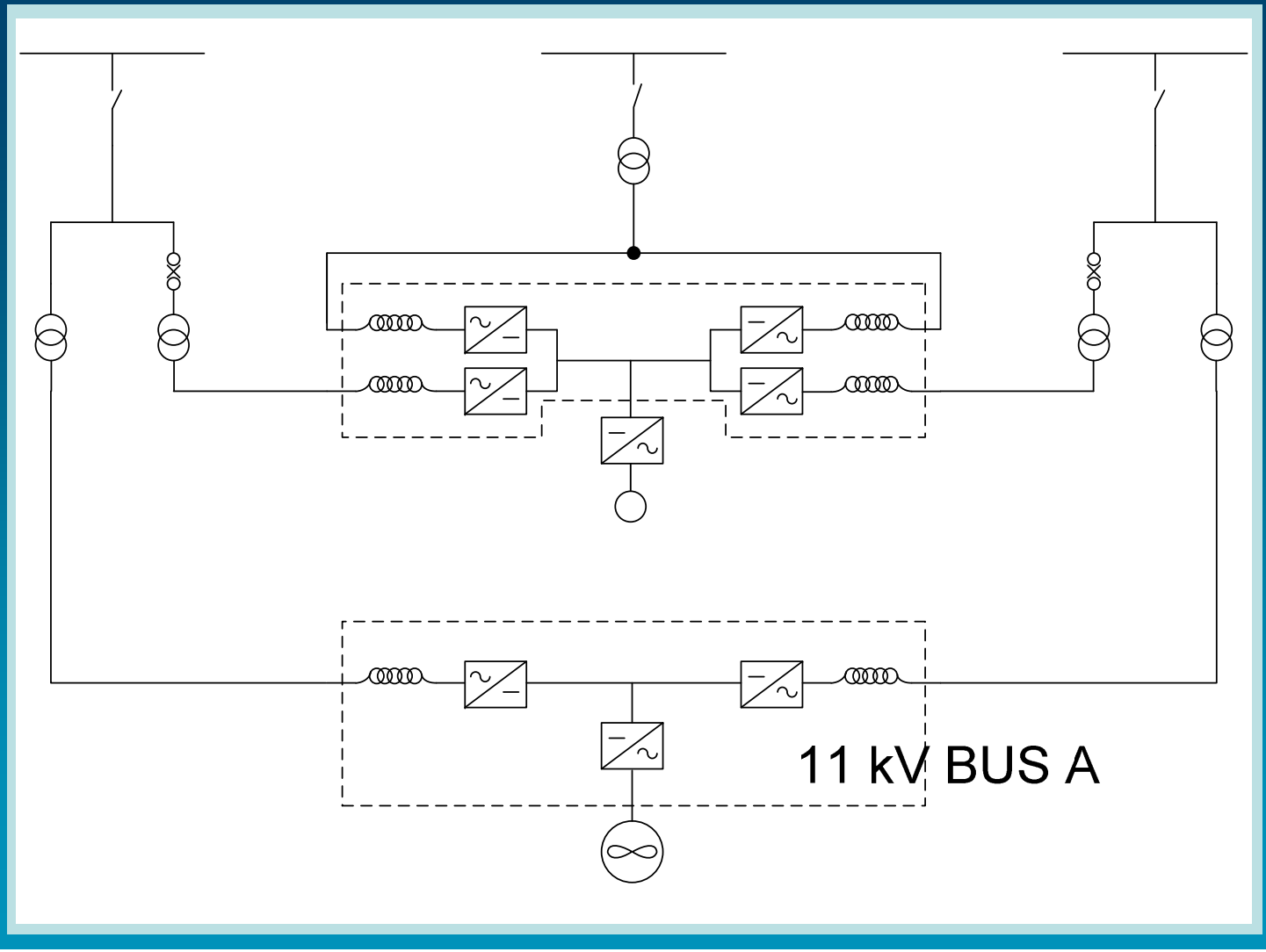
Siplink Based Propulsion System



Siemens' Power Link

Worst Case Failure - Loss of three generators or one thruster – Always two bow thrusters available

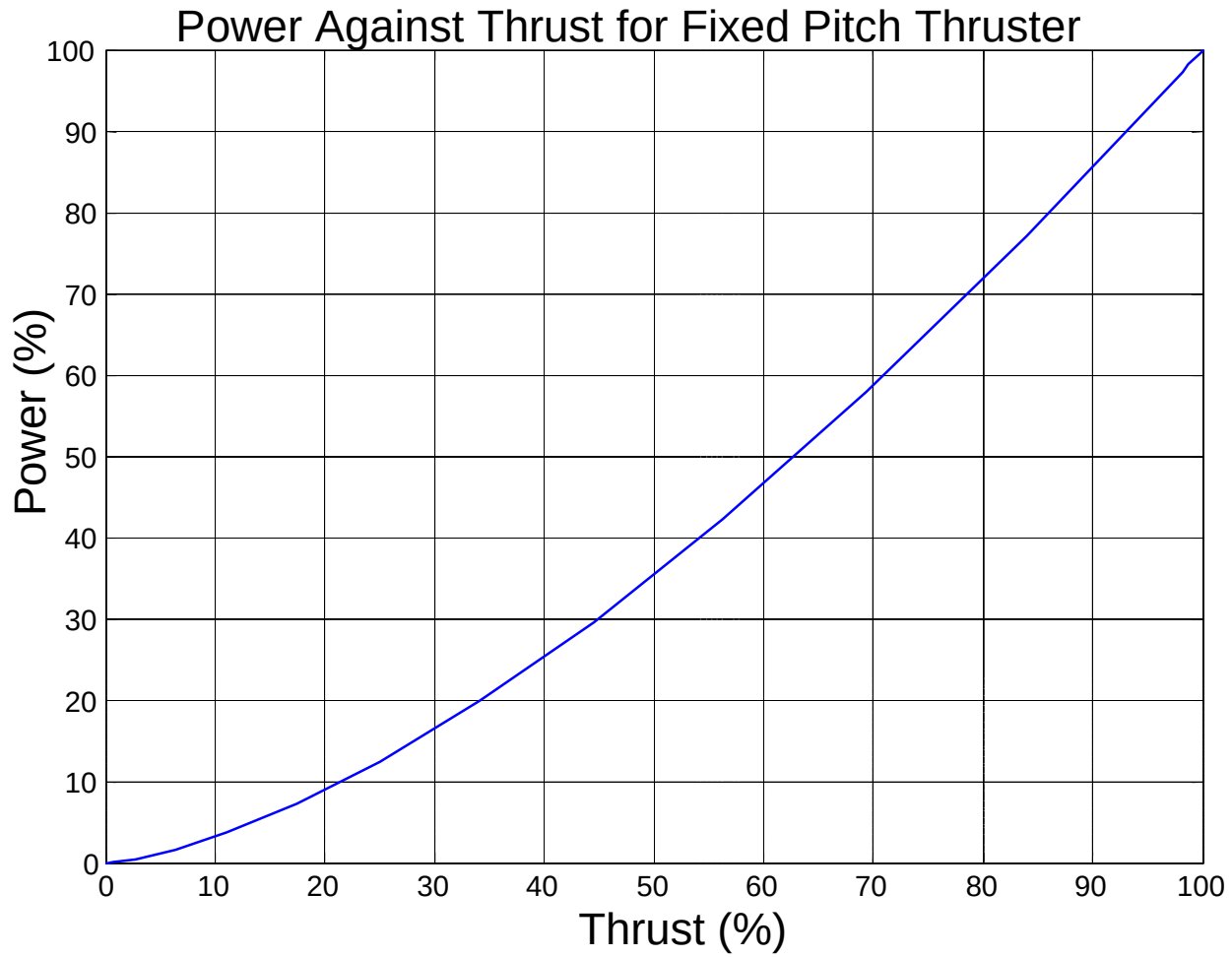
Main and Auxiliary Siplink



Features of ATCP

1. Good fault isolation with main busties open
2. Plant is also fault tolerant with busties closed
3. True dual supply to thrusters and their auxiliaries
4. High levels of thruster independence
5. Draws power only if the bus can supply it
6. Sheds load on falling bus frequency
7. Low impact connection of thrusters
8. Autonomous operation
9. Reduce number of protective functions that lock out thrusters and generators
10. Rapid blackout recovery
11. High thruster availability

High Thruster Availability



Blackout Recovery

- On blackout the Siplink disconnects itself from the bus but remains active waiting for power to be restored. Power is provided by the batteries during this time but can also be drawn from the emergency generator.
- On power restoration the Siplink resynchronises and closes the transformer feeders.
- Pre-magnetising the transformers removes the inrush current transients and so there is no need to wait for two or three generators to connect before restarting thrusters. The DP system can use the thrusters as soon as they become available.
- A considerable amount of time is saved by making thruster and generator recovery a parallel operation rather than a sequential one.

Conclusions

AGP Provides protection against the effects of generator failures including difficult to handle faults such as ‘full fuel’ failures on engines and over excitation of alternators.

ATCP Provides fault isolation, high thruster availability and a range of other features such as rapid load shedding and autonomous blackout recovery.

Together, these features provide a significant improvement in station keeping integrity over conventional power plant designs.