Return to Session Menu

Dynamic Positioning Committee
Marine Technology Society

DYNAMIC POSITIONING CONFERENCE
October 14-15, 2014

GREEN INITIATIVES

Optimizing Energy Efficiency for DP Vessels for Variable Operational Risks

Damir Radan & Steven Mankevich

GE Power Conversion

Optimizing Energy Efficiency for DP Vessels with Variable Operational Risk

Damir Radan & Steven Mankevich
GE Power Conversion
Oct. 2014 , MTS DP Conference, Houston

Imagination at work.

Offshore Industry Challenges

- Availability
- Operating costs
- Capacity
- Reduced CAPEX
- Hostile environment
- Safety standards

imagination at work

Operational cost saving potential versus the operational risks

- **Closed bus** operation provides the potential of **operational cost savings** e.g. less running gens results in savings in fuel, emissions and running hours
- However, with closed bus the **operational risks are higher** than with the open bus system configuration, assuming open bus system is designed for the full autonomy (completely autonomous redundancy groups)
- The risk examples: Partial or total blackout, high transients and danger of system instability, risk of damage to components, complex relay protection system, complex generator protection system, etc. – although the power system is designed to handle all mentioned
- There is a number of power system operational modes - all are **not equally prone** to number of failure modes – we know modes of higher risk
- Requirements for system testing for closed bus systems: **Live full voltage short-circuit tests**
- Closed bus operation is weather and operation dependent and does not always provide significant OPEX benefits at all operational modes
- This paper aims to provide detailed overview of OPEX cost sensitivity to power system risks

imagination at work

Risk reduction methods of closed bus operation

1. Possibility to **run the system with open bus** at higher power load profile without impact to operating costs throughout the year
2. Possibility to run the system within few **specially selected power system operational modes** – e.g. will significantly simplify the relay protection requirements for closed bus and minimize the risk of relay protection malfunction at all conditions
3. Possibility to use the **energy storage (ES)** in order to support (minimize the risk):
   1. The system fault ride through – ES support
   2. Voltage loss ride through – ES support
   3. The system blackout ride through: ES support in 1.) *keep alive mode* or 2.) *partial load support mode*
   4. The variable/cyclic load support: e.g. propulsion load, drilling load – Limited mainly due to size & weight considerations for ES

imagination at work

Closed bus operation support using Energy Storage (ES)

- **Two functional applications**
- Load levelling (i.e. active heave compensation)
- Security of supply (instant black start, spinning reserve)
- **Choice of application/load cycle affects the most suitable ES technology**
- **Two possible locations for ES**

1. DC Drilling Bus
- Optimum security to drilling. Best position for load levelling.
- Easiest exploitation route for LV as LV ES has highest TRL.
- Generator Bus can be supported through DC/DC converter with a DC Arch.

2. Generator Bus
- Optimum security to power system and position with generator fault.
- Not available to support drilling on network fault.
- Require HV ES (lower TRL), or interpose DC/DC converter, additional equipment.

imagination at work

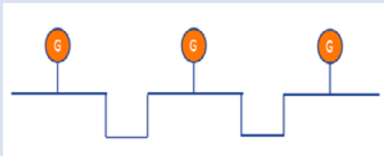
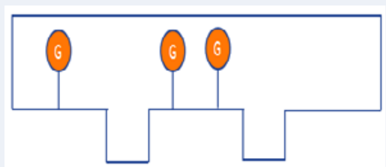
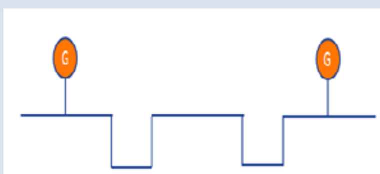
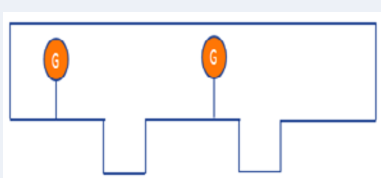
Closed bus operation support using Energy Storage (ES)

Improving vessel operation in closed bus operation will have the following impact if ES technology is used:

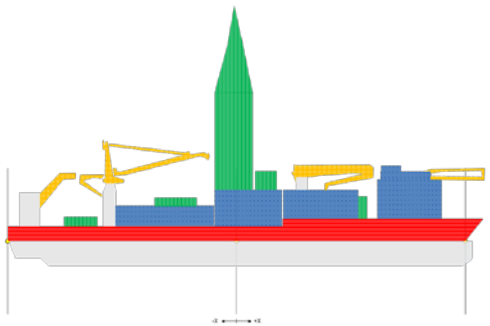
Enhanced functions required for closed bus operation	Eneregy storage support
More segregation (autonomous systems with decentralised functions)	No. Still required.
Less diesel engines required for the same operational profile	Yes.
Improved power system stability	Yes. Using ES posibility to regulate active power through e.g. peak shaving and reactive power by mitigating system over-voltage (depend on ES location)
Proactive action taken on diesel generators and main switchboard	No. Still required.
Integration and coordination on all protection functions	Yes. Protecton complexity reduced with ES. System coordination requirements more relaxed.
Higher fault integrity of the system / Back-up	No. But, system coordination requirements could be relaxed.
Ensuring fault ride through of thrusters and ready to reengage to ensure good recovery	Yes. No, but no need to reengage.
Ensuring fault ride through of LV equipment	Yes.
Quicker and more reliable blackout recovery	Yes. Blackout risk is reduced.

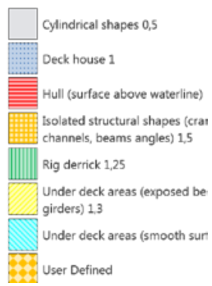
imagination at work

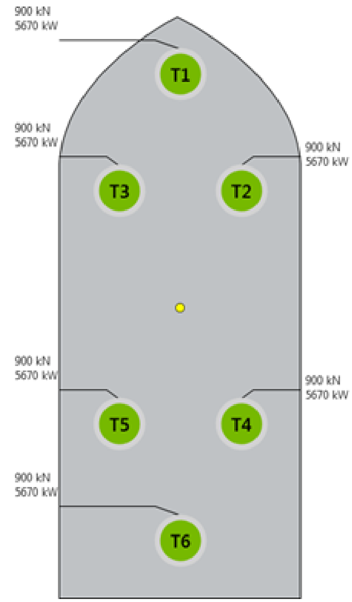
Risk related operational modes

Gens running online	Simplified sketch	Operational mode description	Pros and Cons
1 + 1 + 1		Ring is not used One gen must be connected per switchboard	Pros: Easy and reliable protection Operational cost savings
1 + 2	 Or other any similar combination	Ring is used Two gens connected at one switchboard	Pros: Good operational flexibility Cons: Requires more complex protection No possibility for operational cost savings in traditional DP2/DP3 closed bus notations (AUTR, AUTRO) as gens load must be <33%
1 + 00 + 1		Ring is not used Gens at separated engine rooms must be running Only generators at port and starboard engine rooms can be used, not allowed to use generators in the mid-ship when only 2 online	Pros: Easy and reliable protection Same operational cost savings as with any other combination Cons: Limit of operating flexibility as no gens allowed to run in the middle section when only 2 gens online
1 + 1	 Or other any similar combination	Ring is used Gen running anywhere in the system, but not within the same zone	Pros: Good operational flexibility Good operational cost savings Cons: Requires more complex protection. More failure modes. More testing required.

Calculation of weather dependant load profile on thrusters – VeSpa tool GE

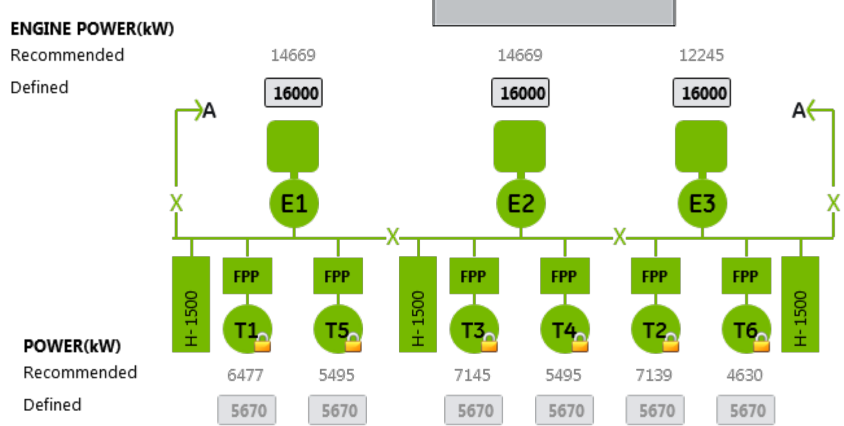






	Type	Control	Max Thrust		Max Power
			+kN	-kN	kW
T1	Azimuth	FPP	900.00	0.00	5670.00
T2	Azimuth	FPP	900.00	0.00	5670.00
T3	Azimuth	FPP	900.00	0.00	5670.00
T4	Azimuth	FPP	900.00	0.00	5670.00
T5	Azimuth	FPP	900.00	0.00	5670.00
T6	Azimuth	FPP	900.00	0.00	5670.00

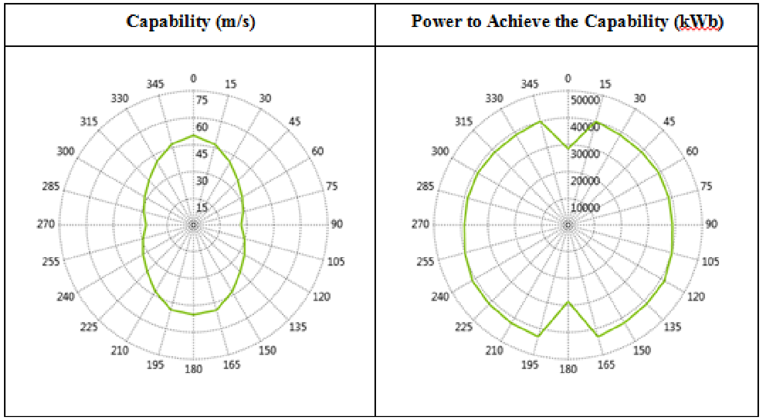
Wave Spectra basis	PIERSON_MOSKOWITZ
Mean Wind Speed Duration	Hourly Mean
Barred Zones	None Defined
Anti Scissor Groups	None Defined
Control Margin	25% of wind force



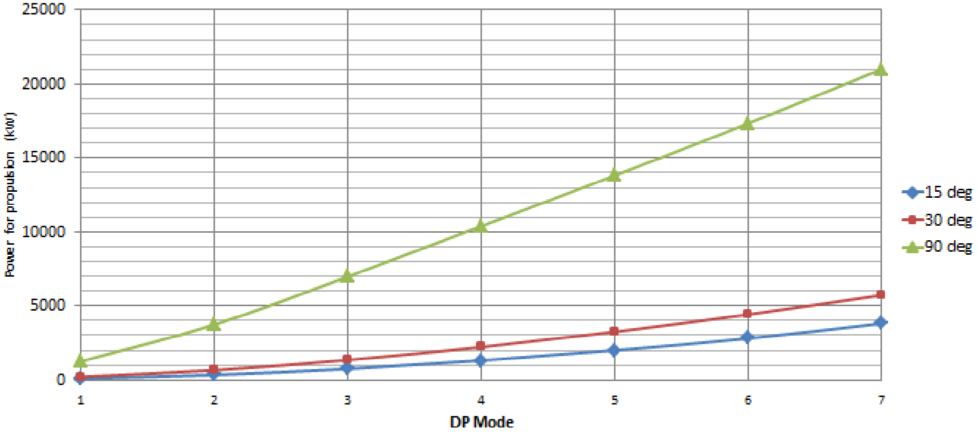
imagination at work

Calculation of weather dependant load profile on thrusters – VeSpa tool GE

Max DP Capability



Propulsion load required in various weather conditions

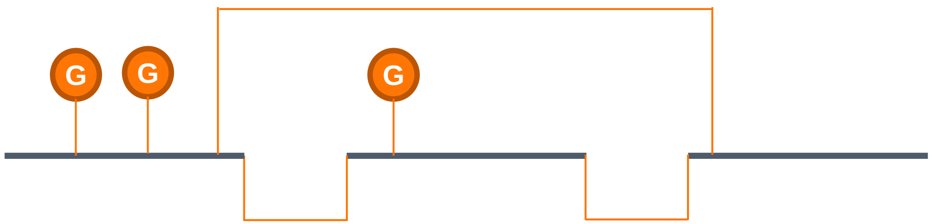


Gulf of Mexico weather profile used for the calculations, see e.g. Aalbers *et* al, MTS DP Conference, 2006

The wave spectrum used in the calculation is the two parameter (1967) spectrum, similar to that adopted by the ISSC(1967) as nominal and wind speeds represent an hourly mean value

imagination at work

Class Notation Dependant Operating Modes

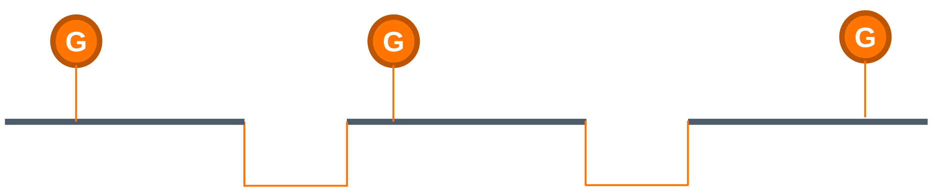


Gen load limit ≤ 33% in Closed Bus DP2/DP3 traditional

CASE 1: Two Gens per bus allowed when 3 gens online

Any other combination allowed with 2 or 4,5 gens online

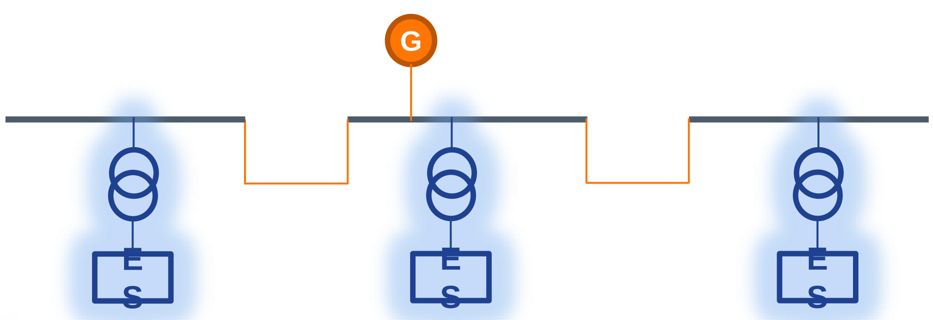
In some modes requires 4 gens online instead of only 2 gens



Gen load limit ≤ 66% in Closed Bus DP2/DP3 traditional

CASE 2: One Gen per bus allowed when 3 gens online

Any other combination allowed with 2 or 4,5 gens online



CASE 3: With energy storage – assumption:

- Allowed to have any single gen online
- Any generator running combination is alowed

Class Notation Dependant Op. Modes

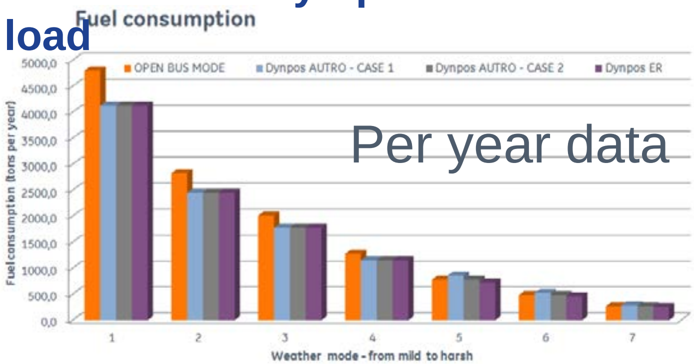
Mode number	Mode description	Case scenarios	Examples:			Total Gens On	Allowed gen load in OPEN bus mode	Allowed gen load in Dynpos AUTRO – CASE 1	Allowed gen load Dynpos AUTRO – CASE 2	Allowed gen load in Dynpos ER	Allowed gen load in Dynpos ER with energy storage
			Gen in Sec 1	Gen in Sec 2	Gen in Sec 3						
1a	With energy storage	Case 3 only	1			1					70-80 %
1b		Case 3 only		1		1					70-80 %
1c		Case 3 only			1	1					70-80 %
2	1 gen at each of two swbds and 1 swbd without running gen	Case 1 and 2	1		1	2		50 %	50 %	70-80 %	70-80 %
3a	1 gen per swbd	Case 1	1	1	1	3	50 %		67 %	70-80 %	70-80 %
3b	2 gens + 1 gen (2 gens at one swbd and 1 gen at another swbd)	Case 2	2	1		3		33 %		70-80 %	70-80 %
4	2 gens + 2 gens	Case 1 and 2	2	1	1	4		50 %	50 %	70-80 %	70-80 %
5	2 gens + 2 gens + 1 gen	Case 1 and 2	1	2	2	5		60 %	60 %	70-80 %	70-80 %
6	All generators running	Case 1 and 2	2	2	2	6	100 %	100 %	100 %	100 %	100 %

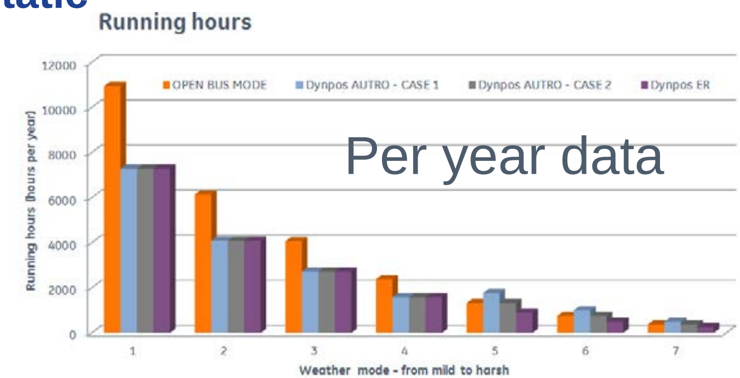
$$\textbf{Load Limit} = (N_{on} - MaxNbus) / N_{on}$$

imagination at work

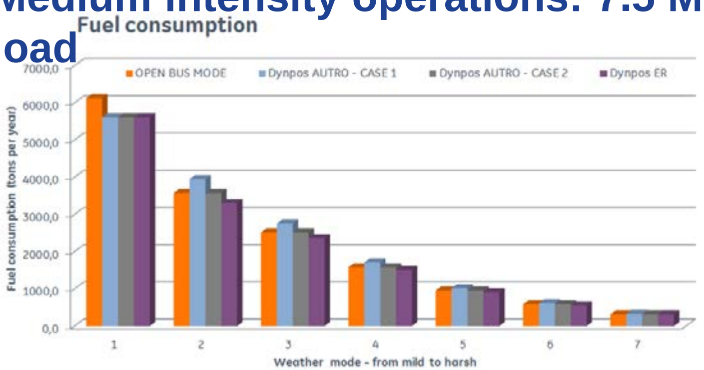
Results – weather mode dependant

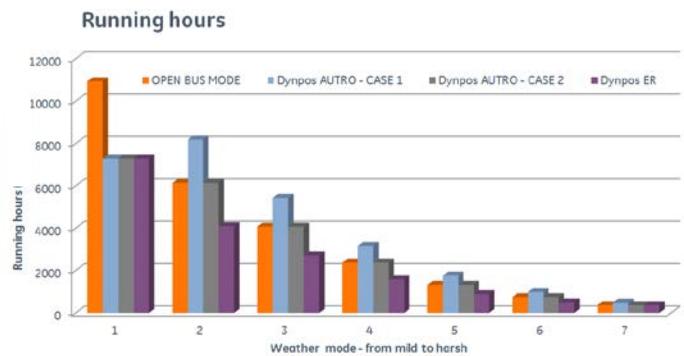
Lower intensity operations: 5.0 MW static load



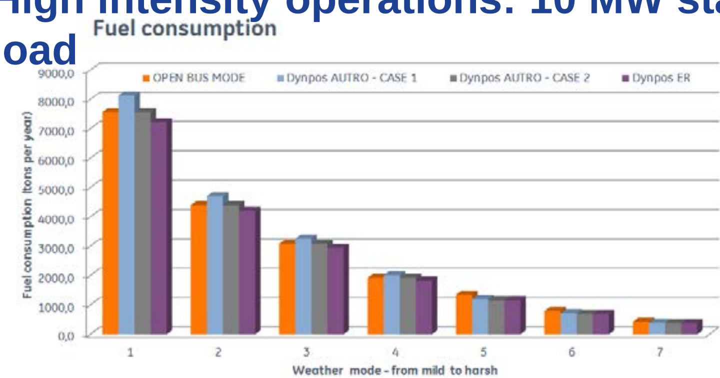


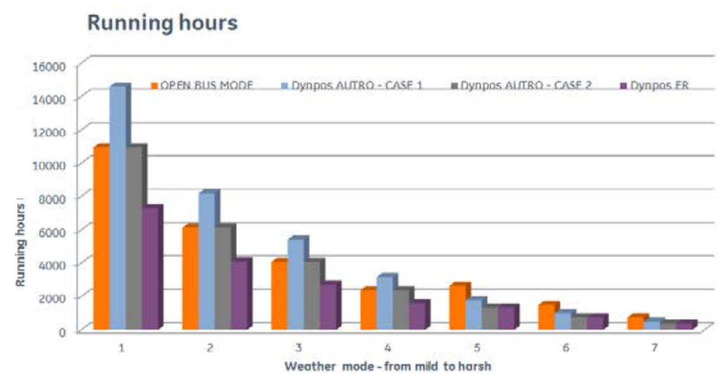
Medium intensity operations: 7.5 MW static load





High intensity operations: 10 MW static load





Results – overall

Lower intensity operations: 5.0 MW static load

	OPEN BUS		*CLOSED BUS - Dynpos AUTRO - case 2*		*CLOSED BUS - Dynpos AUTRO - case 1*		*CLOSED BUS - Dynpos ER*		*CLOSED BUS - Dynpos ER & Energy Storage in Stand by mode*	
	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL
	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)
	Heading = 30 deg		Heading = 30 deg		Heading = 30 deg		Heading = 30 deg		Heading = 30 deg	
Only in DP	100,0 %	100,0 %	88,7 %	69,8 %	89,8 %	67,6 %	87,9 %	66,7 %	81,1 %	39,5 %
	Heading = 90 deg		Heading = 90 deg		Heading = 90 deg		Heading = 90 deg		Heading = 90 deg	
Only in DP	100,0 %	100,0 %	94,5 %	78,2 %	97,7 %	91,4 %	91,6 %	63,1 %	89,2 %	51,2 %

Medium intensity operations: 7.5 MW static load

	OPEN BUS		*CLOSED BUS - Dynpos AUTRO - case 2*		*CLOSED BUS - Dynpos AUTRO - case 1*		*CLOSED BUS - Dynpos ER*		*CLOSED BUS - Dynpos ER & Energy Storage in Stand by mode*	
	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL
	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)
	Heading = 30 deg		Heading = 30 deg		Heading = 30 deg		Heading = 30 deg		Heading = 30 deg	
Only in DP	100,0 %	100,0 %	96,7 %	86,0 %	102,2 %	89,5 %	93,1 %	67,1 %	93,1 %	67,1 %
	Heading = 90 deg		Heading = 90 deg		Heading = 90 deg		Heading = 90 deg		Heading = 90 deg	
Only in DP	100,0 %	100,0 %	97,6 %	88,3 %	101,6 %	105,0 %	92,9 %	60,9 %	92,9 %	60,9 %

High intensity operations: 10 MW static load

	OPEN BUS		*CLOSED BUS - Dynpos AUTRO - case 2*		*CLOSED BUS - Dynpos AUTRO - case 1*		*CLOSED BUS - Dynpos ER*		*CLOSED BUS - Dynpos ER & Energy Storage in Stand by mode*	
	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL	Fuel Consum.	Running hours TOTAL
	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)	(tons/voyage)	(hr/voyage)
	Heading = 30 deg		Heading = 30 deg		Heading = 30 deg		Heading = 30 deg		Heading = 30 deg	
Only in DP	100,0 %	100,0 %	98,3 %	95,9 %	104,5 %	127,9 %	94,3 %	66,9 %	93,7 %	64,4 %
	Heading = 90 deg		Heading = 90 deg		Heading = 90 deg		Heading = 90 deg		Heading = 90 deg	
Only in DP	100,0 %	100,0 %	95,7 %	78,7 %	96,7 %	84,5 %	92,6 %	59,3 %	90,5 %	51,7 %

imagination at work

Points to consider

OPEX cost savings comparison with open bus

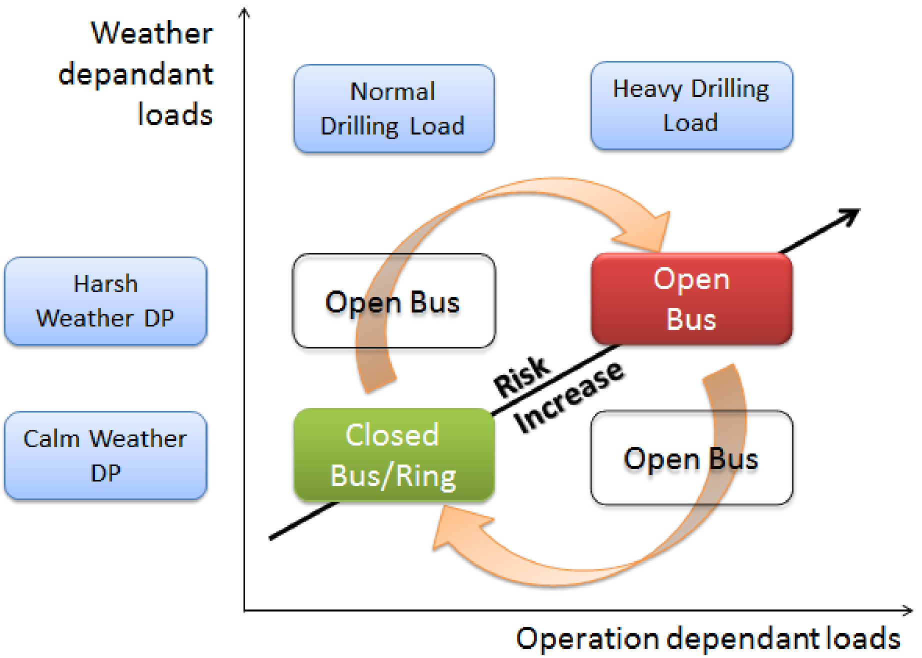
Operation Load Intesity	Closed Bus DP2/DP3 traditional - CASE 1 (min 0 gens at bus)		Closed Bus DP2/DP3 traditional - CASE 2 (min 1 gen at bus when 3 online)		Closed Bus DP3 Enhanced (ER/E)		Closed Bus DP3 Enhanced (ER/E) with Enery Storage (ES) – CASE 3	
	Fuel	Run Hous	Fuel	Run Hous	Fuel	Run Hous	Fuel	Run Hous
Lower	10%	30%	10%	30%	10%	30%	**≈20%**	**≈60%**
Medium	3%	14%	- 2%	10%	7%	30%	7%	30%
High	2%	4%	- 4%	- 25%	5%	30%	6%	35%

- All notations equivalent if the operational intensity is low (low static load)
- Energy storage benefit is high for operations of low intensity (low static load). Additionally the load peak shaving capabilities are also more required due to low generating capacity engaged (although not considered in the comparison)
- DP3 Enhanced Notation provides the highest OPEX benefits at all operational scenarious

imagination at work

Load dependant operational mode switching concept

- All Closed Bus modes provide high OPEX cost savings in low intensity operations
- In Medium and High intensity operations Open bus mode provides higher benefits than Closed bus CASE 1 mode (0 gens allowed at bus)
- ER mode provides the best opex cost savings in all operational scenarious
- All modes are weather dependant, 80-90% fuel consumption occurs at weather modes 1 to 4
- The benefit of closed bus is of low significance when weather higher than mode 5 →can switch to Open Bus mode



Conclusion

- **Closed bus** operation provides the potential of **operational cost savings** (savings in fuel, emissions and running hours)
- With closed bus the **operational risks are higher** than with the open bus system
- Power system operational modes are **not equally prone** to failure modes – we know which modes are of higher risk
- All Closed Bus modes provide **high OPEX cost savings in low intensity operations**
- **ER mode provides the best opex cost savings** in all operational scenarious
- All modes are weather dependant, **80-90% fuel consumption occurs at low weather modes (1 to 4)**
- The benefit of closed bus is of low significance when weather higher than mode 5 → **can switch to Open Bus mode**
- **Energy Storage can provide great deal of support to mitigate number of risks** related to closed bus operation, although it has limited application for cycling loads and permanent energy support

imagination at work

Thank you

Imagination at work.