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GREEN INITIATIVES SESSION

Demonstrating the Benefits of Advanced Power Systems and Energy Storage for DP Vessels

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ABB AS, Marine CoE O&G Vessels

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Abstract

Recent advances in shipboard power systems affords designers of marine electrical power systems unprecedented opportunities to improve safety, efficiency and functionality.
With the introduction of the IEC 61850 communication standard in marine power systems new opportunities for increasing the operational performance of DP drilling vessels have been made possible by introducing enhanced features like:

- Block based protection functions.
- Ultra-fast load reduction schemes.
- Enhanced engine and generator protection functions integrated in the main power switchboards.

The first closed-ring DP drilling vessels based on this new comprehensive protection platform have now been commissioned and results confirm predictions in [1] and [2]. In practice, this means that time critical protection requirements relating to balance of power and black-out prevention, short-circuit protection and power-plant monitoring; are handled within the confines of the switchboard and main consumers, yielding a very quick and fault tolerant power system – even in the absence of overriding systems like the PMS.
Complementing, and arguably rivalling this protection platform in potency; energy storage and more advanced power electronic converter systems are making an entry into shipboard power systems. If strategically integrated, these systems can dramatically improve the main power system's fault-tolerance and performance, whilst at the same time reducing main engines' fuel consumption and running hours. Improved fault tolerance and performance can be achieved through a combination of:

- Using energy storage to bridge power and energy demand during excessive power demand or main engine failures
- Reducing or eliminating black-out recovery times by keeping sections of the power system energized during outages.
- Supply critical consumers like propulsion and drilling drives with dedicated energy storage units to both act as an energy buffer for quick load transients and provide an enhanced ride-through capability for these loads.

By improving the system in these ways, it becomes possible to run the power system with fewer engines online, thereby increasing their partial loading which in turn improves specific fuel oil consumption and reduces low-load induced maintenance costs. Running fewer engines also reduces accumulated running hours of the power plant.

This paper will include sea-trial measurements for one drillship, demonstrating the effectiveness of the new protection platform, including:

- Ultra-fast load reduction on generator trip and
- Fault handling by ABBs Diesel Generator Monitoring system on AVR sensor failure.

Further; results from laboratory tests will be used to illustrate the inherent potential in energy storage, including considerations like

- Energy storage systems as spinning reserve and
- The effect on a power system's efficiency and performance if power fluctuations are absorbed using an energy storage system

In conclusion, the marriage between a comprehensive and flexible protection platform and one or more energy storage systems has the potential to revolutionize what we will come to expect from diesel electric power systems.

Introduction

In the last couple of years there has been a growing market demand for operating DP class drilling vessels with closed bus power system, even under the strictest DP requirements. The driver behind this development has been the desire to fully utilize potentials of modern electric power and propulsion systems with respect to operational costs, emissions and flexibility.

For ocean going vessels (e.g. cruise vessels and LNG carriers), where fuel efficiency has had a greater focus, this has been the norm since the dawn of electrical propulsion.

The notable difference lies within the operational principles established for each vessel segment, where ocean going vessels have had fuel efficiency as their main focus while station keeping DP vessels have had blackout prevention as theirs. The simplest way to achieve the latter is to operate the power system in a split configuration with two or more independent power systems. This, however, comes at the cost of having to operate with excessive online generating capacity to meet DP requirements for spinning reserve. This, in turn, results in lower average loads and consequently worse operating conditions for more engines; pushing operating costs up.

Today the fuel efficiency and operating costs are getting a higher priority, also for drilling vessels. This translates to requirements for closing the transfer breakers under operation whilst maintaining (or even increasing) open-bus-safety levels.

As a result, provisions have had to be made to existing power plant designs in order to prove an equal integrity towards any imaginable fault condition.

As described in [2], current products and system design have aligned themselves and a new generation of protection relays, communication standards like IEC 61850 and compliant automation systems have made closed bus operation a reality.

New on the scene is Energy Storage (ES) which holds the promise of further improvements in performance and efficiency in station keeping vessels.

In this article we will review how some of the technologies described in [2] have worked in practice and explore the new potentials offered by ES solutions in DP vessels. Finally we will compare the step-wise improvements in key parameters as an example drilling vessel makes the transition from Split system operation $\Rightarrow$ Closed ring operation $\Rightarrow$ Closed ring operation with ES.

Closed Bus Operation Solutions in Practice

Closed Bus Operation Requirements

Both DNV and ABS have issued new and revised rules for Dynamic Positioning systems with requirements for closed bus operation in DP. These are described in [3] and [4]. Together with market driven requirements and technology developments – both in more advanced and intelligent devices and system configurations – the main closed bus requirements are summarized below:

Requirement	***Practical Application***
Enhanced and robust power plant design	Implementation of zone protection with fast failure detection and discrimination of failed components or systems. The zone protection acts as the primary protection function, and the traditional time-current selectivity settings will still function as backup protection in case of severe communication faults.
Resistance to hidden failures	Protection with backup arrangement as alternative action to isolate faulty system or components, and self-diagnostic.
Enhanced Generator Protection system	Protection for • over- and under-fuelling • over- and under-excitation • faulty load sharing.

	These are failures modes not normally covered by traditional protection relays; but methods to deal with them are considered an integral part of the system protection and should consequently be integrated as part of the overall protection system.
Autonomous systems	Autonomous and decentralized thruster and generator systems to achieve segregation in order to minimize the effect of failures and dependencies.
Blackout prevention	Fast load reduction in large consumers (mainly thruster and drilling Variable Speed Drives) to avoid overload due stopping/tripping of one or more generators
Fast blackout recovery	With no manual interaction and full thruster control on DP within 45s, according to [3].
Transformer pre-magnetising	For reduction of large inrush currents and related voltage dip (mainly thrusters and drilling supply transformer) especially with one generator out of service.
Fault ride through capability	For essential systems, especially on the low-voltage distribution side. It is important that faults are cleared as quickly as possible so time delay in under voltage devices and other fault tripping delays can be minimized.

Most of these requirements are also increasingly being met by newer DP power systems without closed bus tie requirements and are gradually becoming part of the standard DP power system offering. What differentiates these systems to those operated with closed bus tie is the need to prove that the latter has the same or higher integrity as the former. The means by which to get acceptance for this is to perform comprehensive FMEAs and full scale testing on-board after installation and commissioning. In the following sections a selection of such real test results will be shown.

Enhanced Generator Protection System – DGMS

The purpose of the Enhanced Generator Protection System is to protect against faults that are not handled correctly by traditional protection relays. These include:

- over- and under-fuelling
- over- and under-excitation
- faulty load sharing.

The challenge with these faults is that it is often not sufficient for a protective device to monitor only one diesel generator as this will give the device an incomplete picture and could result in it taking action to the detriment of the rest of the system. For this reason ABB has developed and commissioned an Enhanced Generator Protection System called DGMS (Diesel Generator Monitoring System) that address this problem and uses information about the whole power system to make an informed decision on how to best – from a system perspective – alleviate the problem. Since the DGMS functions are programmed in IEC61850-enabled PLCs which can communicate directly with the new protection relays; DGMS' integration into the main switchboard is a natural extension of the switchboard's protection system. These enhanced protection functions are specified directly in the new enhanced DP class requirements from ABS [4] and DNV [3].

Over-excitation can happen if a generator's Automatic Voltage Regulator (AVR) loses its voltage measurement and as a result increases it excitation current to counteract the perceived voltage drop.

If two generators G1 and G2 are operating in parallel and G1 develops an such a condition, this would result in G2 perceiving itself to be under-excited. After a delay of a few seconds G2's protection relay would trip and G1 would be left alone on the net with no other generator to limit its voltage and G1's

protection relay would trip on overvoltage after a delay of a few seconds and the bus would be dead. Figure 1 shows what happens if the same system has DGMS installed.

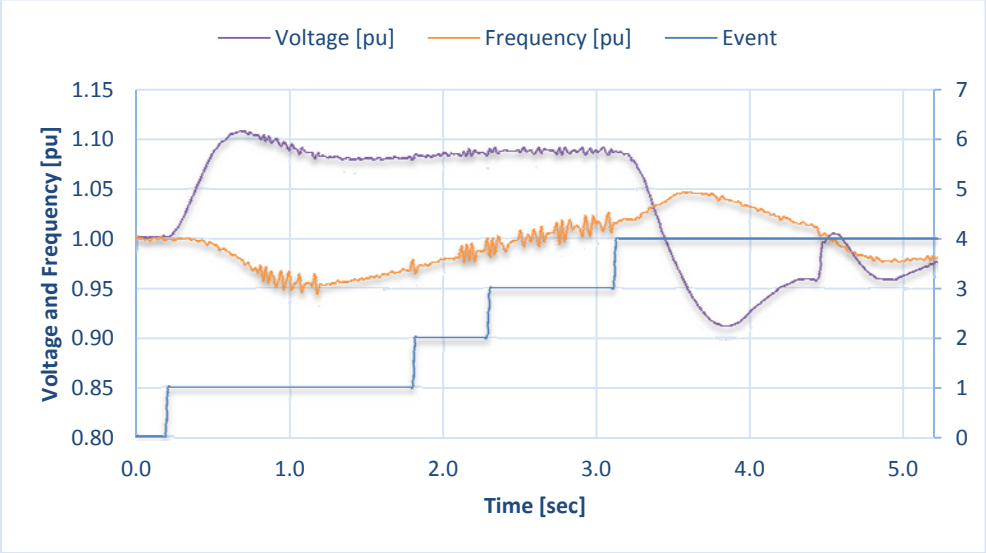

Figure 1 Voltage and frequency of G1 during an over-excitation fault where the generator is taken out by the switchboard-integrated DGMS system.

The graph and the table below shows that the DGMS successfully identifies the faulty generator and segregates it from the bus, whilst giving the PMS ample time to prepare for the loss of a generator set. In this example the DGMS waits for reverse reactive power on G2 before it trips G1.

Event	*Time [s]*	*Event Description*	*DGMS Action*
1	0.2	Voltage outside of correlation limits	Detects fault and sends alarm if fault is still active after 1.5seconds
2	1.8	DGMS Alarm	Sends alarm and delays tripping 0.5s to allow PMS to prepare for loss of generator
3	2.3	Trip Sequence	G1 is de-excited and breaker set to trip after 0.7s
4	3.0	Trip	G1 is segregated from switchboard G2 survived – no blackout

Blackout Prevention – Event Based Fast Load Reduction

Another important aspect of black-out prevention is to ensure that generators are not overloaded. This is particularly important during sudden loss of generating capacity. This has traditionally relied on frequency-phase-back functions implemented in large drives which scale back drawn power if the frequency falls below 57.5Hz. After the initial load reduction has been performed by this function, the PMS takes over.

The use of the Goose communication protocol enables very quick communication between the switchboard and heavy consumers like the thruster and drilling drives. An example of the communication infrastructure is shown in Figure 2.

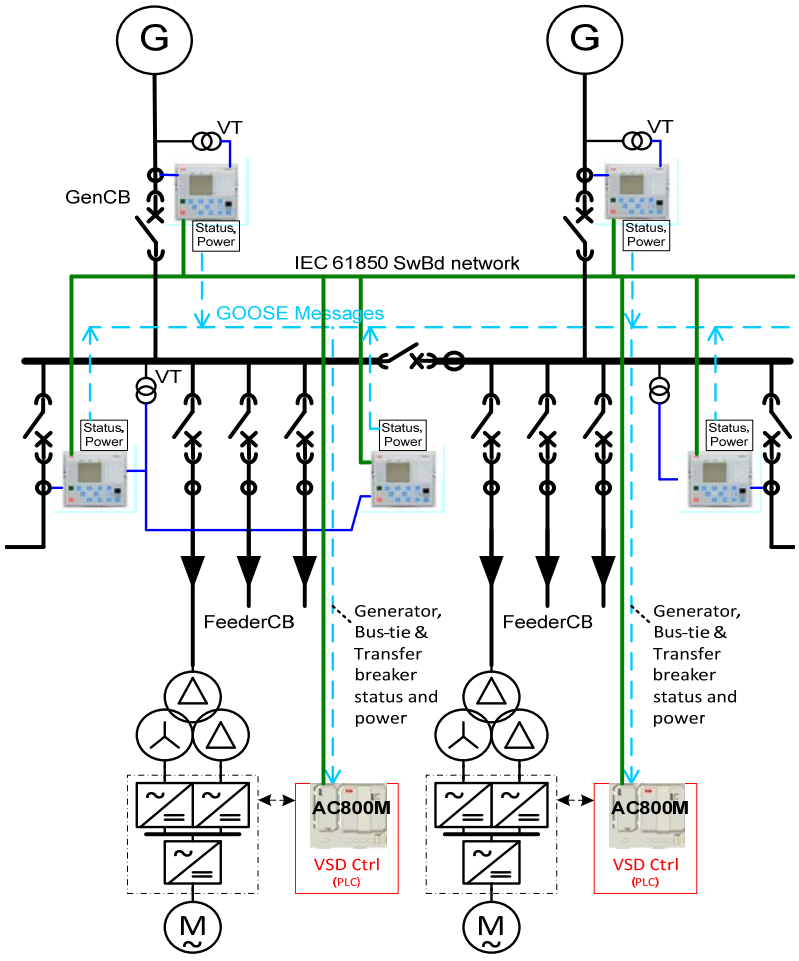

Figure 2 Communication infrastructure in the switchboard and large consumers.

Figure 3 shows the signal flow from the trip module inside a generator breaker relay down to the a frequency converter over the Goose IEC61850 protocol. The speed at which this information is transmitted means that the total elapsed time for a power limit signal to the thruster is <50ms and the VSD (e.g. thruster of drilling drive) will have limited its power consumption autonomously even before the generator breaker has had time to open.

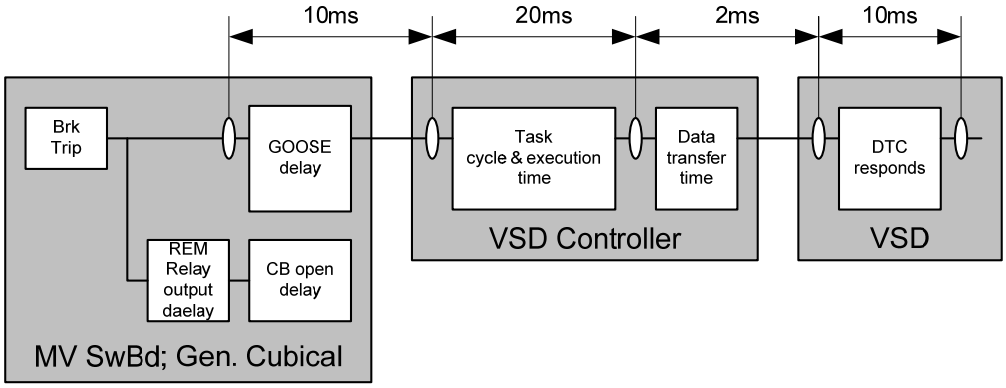

Figure 3 The signal flow from trip module inside a generator breaker relay down to the a frequency converter. The total elapsed time is <50ms, meaning that the vsd (e.g. thruster of drilling drive) have limited power before generator breaker has had time to open.

This system was tested onboard a drillship during the summer of 2014 with very good results. Figure 4 and Figure 5 show the results of a test where three generators were initially loaded to 50%, when generators 3 and 6 were tripped simultaneously, giving generator 4 a potential 100% load step. Figure 5 shows how the thruster reduces its power from 75% to 22% already before the frequency is seen to go down. The resulting load-step seen by G4 is reduced from 100% to 30% and the frequency only falls down to ~57.3Hz before recovering. With the implementation of this near-instantaneous load reduction, the pressure on the PMS to react quickly is significantly reduced.

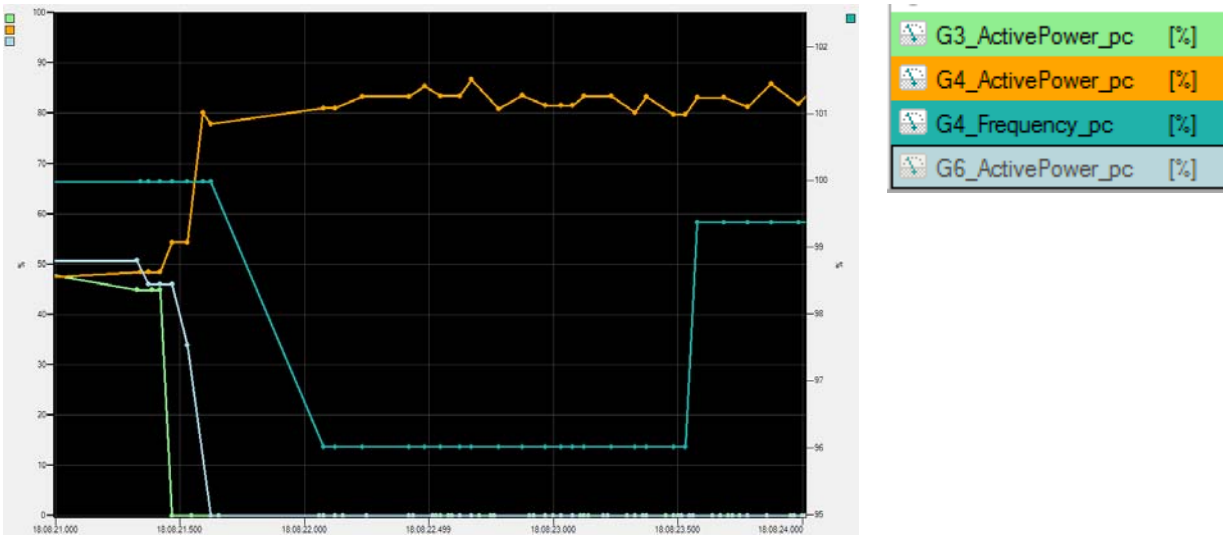

Figure 4 The bus frequency and active power of generators 3,4 and 6. All generators are loaded at 50% when generator 6 and 3 are tripped simultaneously, leaving generator 4 alone on the bus.

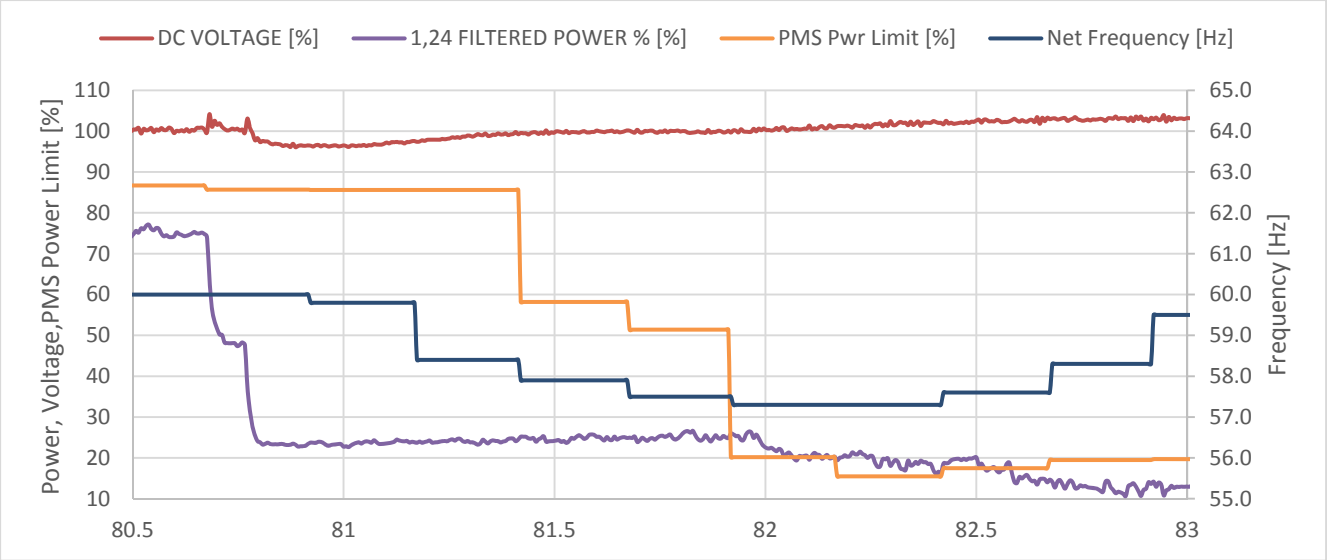

Figure 5 The bus frequency, power limit signal from PMS and active power and internal DC voltage of of thruster drive. All generators are loaded at 50% when generator 6 and 3 are tripped simultaneously, leaving generator 4 alone on the bus. Power on drive is limited before the generator breaker is opened.

Fast Blackout Recovery –Fast Charging with Pre-magnetisation

The requirement of a fast recovery following a blackout stems from the need to reduce the impact of a black-out, should it happen. This also ties in with pre-magnetisation on transformers and autonomous sub-systems and is especially important for thruster systems.

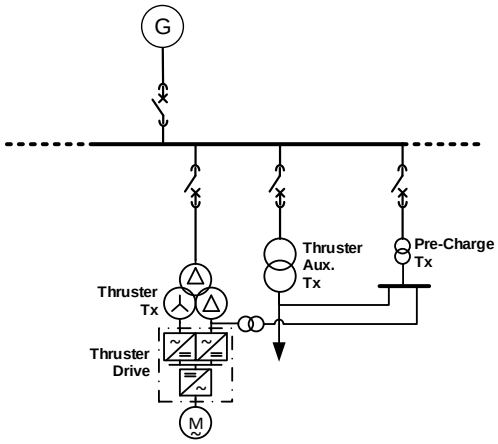

Figure 6 Single line of a thruster system with transformer pre-magnetization for both the auxiliary transformer and the main propulsion transformer. This serves the dual purpose of magnetizing the transformers and pre-charging the thruster frequency converter.

With the combination of:

- autonomous subsystems that drive their own, coordinated start-up sequences,
- under-voltage ride-through of thruster drive,
- pre-magnetisation of transformers that allow quick re-connection and
- the new *fast charging with pre-mag* (FCP) function that simultaneously magnetizes the propulsion transformer and pre-charges the propulsion converter

the recovery time following a blackout has been reduced dramatically.

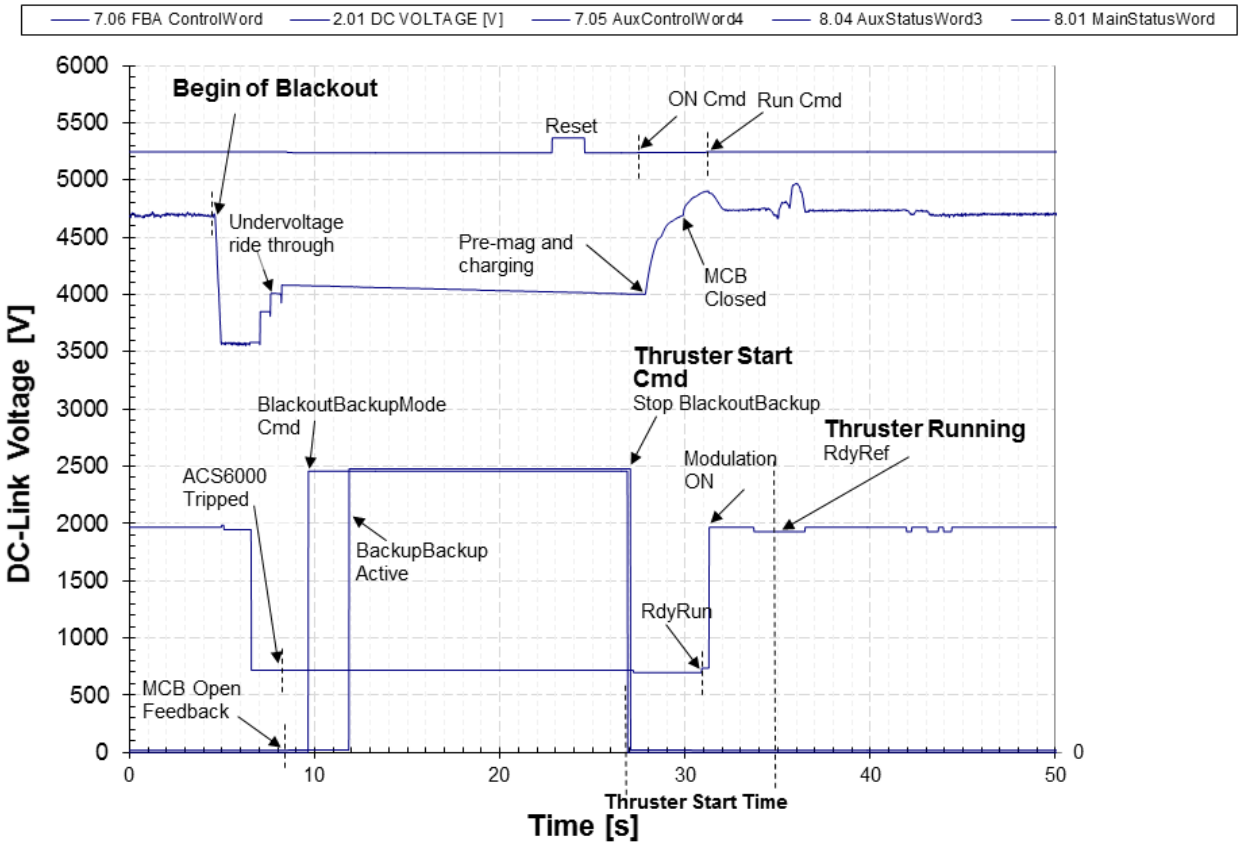

Figure 7 The blackout recovery sequence .

Figure 7 shows the blackout recovery sequence as seen from a thruster drive. The black-out occurs at t=5sec and shortly thereafter the thruster drive enters its blackout backup mode. Power on the main switchboard is restored at t=27sec and the thruster starts its startup sequence. A little before t=35sec – only 30 seconds after beginning of the blackout and 8seconds after power was restored on the main switchboard – the thruster is again following its DP reference signal.

Introducing Energy Storage Systems

ES Technology

Energy Storage (ES) and associated technologies have received a dramatic increase in attention in recent years, not least in the maritime industry. Whilst this can be attributed to a number of different factors, what is certain is that it holds the promise of improving safety, efficiency and performance of future DP vessels. ES media fall into three broad categories; batteries, super capacitors and flywheels, where the first two seem to be gaining ground on the latter. Super capacitors are often favored in repetitive and power intensive applications. Batteries on the other hand have typically suited energy-intensive applications. The battery is, however, slowly encroaching on super capacitor territory with its ever improving chemistries and cooling solutions. Regardless, we are now at a stage where it is economically and technically viable to use ES on an increasingly large scale in marine power systems.

Integrating ES into a Power System

However; the availability of ES only gets you part of the way to improved safety, efficiency and performance. First; the energy must be made available to consumers. As shown in Figure 8, there are three typical ways of doing this, each with inherent advantages depending on application:

1) connecting to the AC network through a static-frequency converter and transformer, or
2) connecting to the internal dc link of a converter through a DC/DC converter
3) connecting to the internal dc link of a converter directly

Also, in the same way that a engines in a section can share a fuel tank, one common ES bank can be shared between multiple converters and in this way made available in multiple points in the system simultaneously.

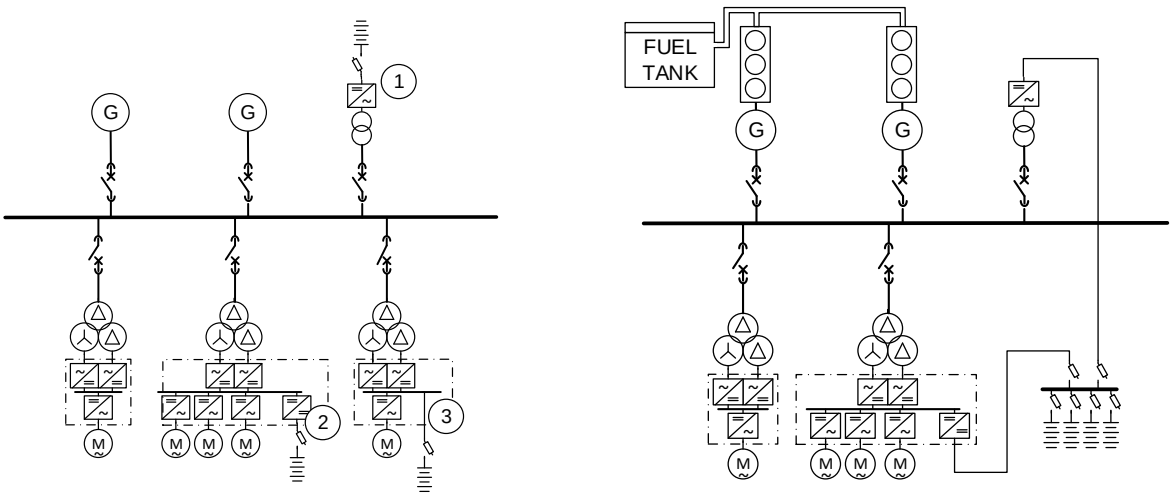

Figure 8 Different methods for connecting ES to a power system and the analogy between ES and fuel tank. Like a fuel tank, an ES unit can be shared between several converters to achieve a more cost efficient dimensioning of the ES bank.

Regardless of which alternative is used, the power-electronic hardware used to control the flow of power in and out of the system remains the same as shown in Figure 9.

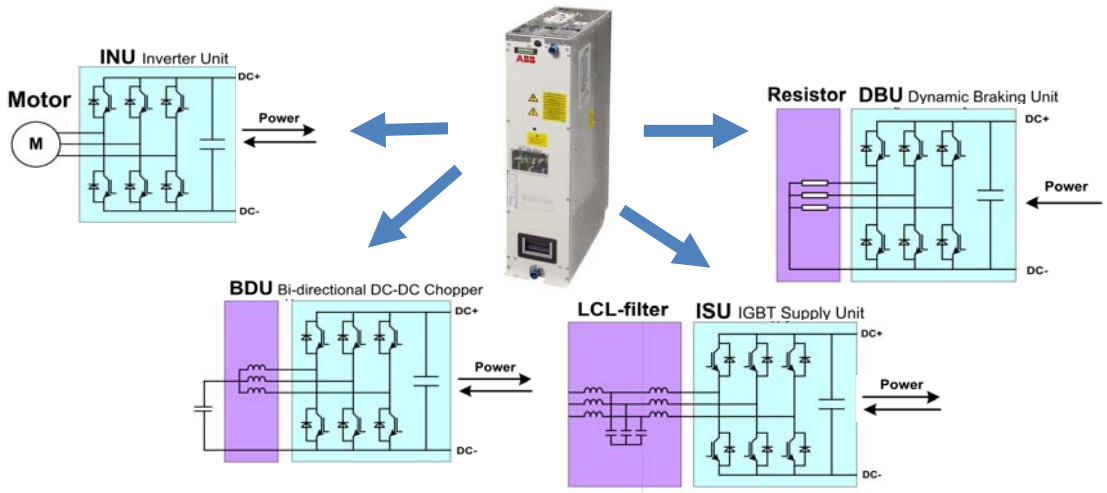

Figure 9 Different converter types in the ACS800/ACS880 industrial LV converter family re-use the same power-electronic building block. Only control software and connection method changes.

Once the most appropriate method and "injection point(s)" have been identified for a particular application, the attention must be turned to how these converters are controlled. In applications where the battery is the main energy source this is relatively straightforward since they can be treated much like a traditional generator. However, in cases where their purpose is to enhance the overall performance of a system, and do so in parallel with diesel generators; this requires more attention. In such systems the ES system can take on a wide range of functions as described below.

Symbol	**Name**	*Description*	*Purpose*
	Spinning Reserve	Unit is connected and running but not charging or discharging energy into the system. On loss of generating capacity it steps in to take the load for a predefined period of time. If other functions are activated simultaneously, this function ensures that sufficient energy is left in battery.	• Backup for running gensets • Fewer engines needed online • Improved fuel efficiency • Reduced engine running hours
UPS	***Enhanced Ride Through***	Same as spinning reserve, but on a local level in a sub-system like a thruster or drilling drive.	• ES storage solutions can give UPS like functionality for all or portions of power system • New ways of achieving higher ERN numbers • Higher power system availability
	Peak Shaving	Unit absorbs load variations in the network so that engines only see the average system power.	• Level the power seen by engines • Offset the need to start new engine • Improved fuel efficiency • Reduced engine running hours

	Enhanced Dynamic Performance	Unit absorbs sudden load changes and then ramps the change over on running engines. If peak shaving is used, then this function is automatically included.	• Instant power in support of running gensets
			• Enable use of «slower» engines;
			  • LNG/Dual Fuel engines
			  • Fuel Cells

OPTIMAL	***Strategic Loading***	Unit charges and discharges to optimize the operational point of running engines, ensuring that energy is produced at the lowest cost, taking the efficiency of the ES system into account.	• Charging and discharging ES media in such a way that it optimizes the operating point of the gensets. • Power is produced at peak efficiency
0 CO_2 NO_x dB	***Zero Emissions Operation***	Unit powers the system so that engines can be turned off.	• Zero emissions in harbor • Quiet engine room

Sometimes these functions will work alone and other times in unison. Whilst many of these functions have different names, tying them to different applications or roles in the power system, they will often share the same low-level functionality. One such example *is Spinning Reserve* and *Enhanced Ride Through* that both step in to cover a sudden generation power loss in the system.
To demonstrate two of these functions, *Spinning Reserve* and *Enhanced Dynamic Support*, three test runs have been performed in ABBs laboratory at MARINTEK in Trondheim. These are included here below.

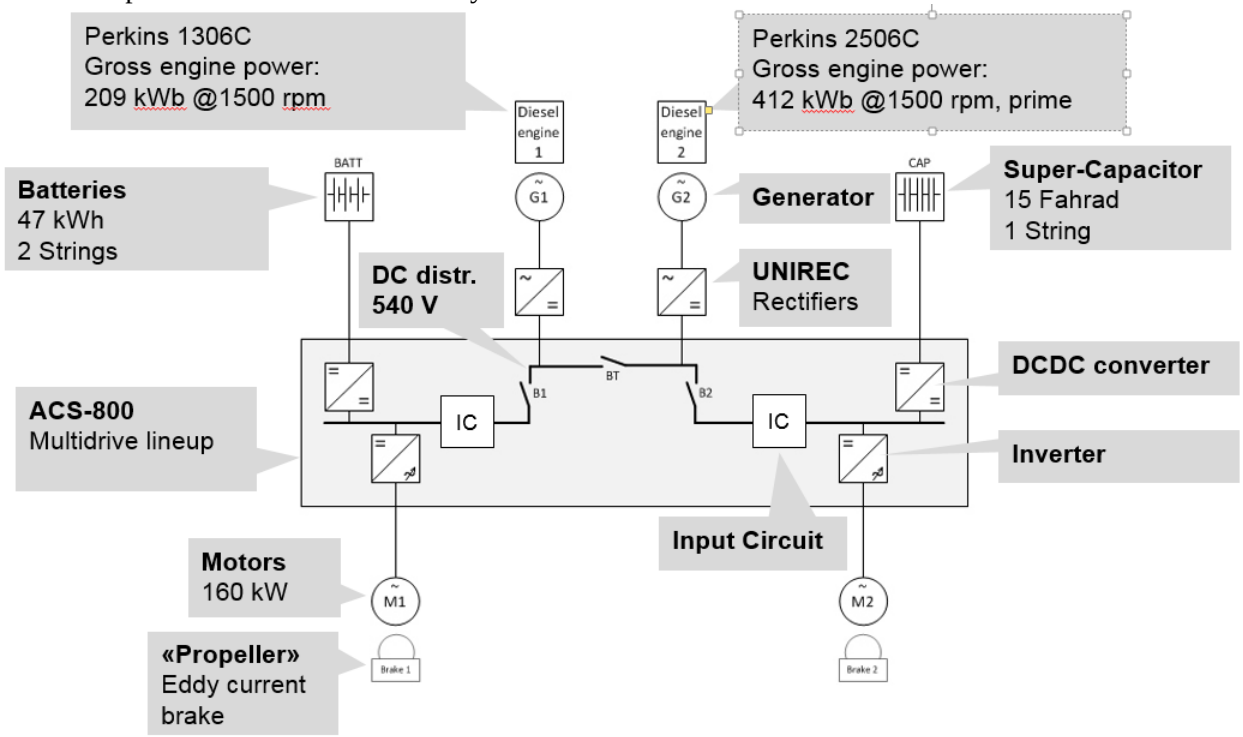

Figure 10 Simple schematic of the power system used during the test runs.

Generator 2 was started and a variable load which oscillated between ~5 and 85kW with a period of ~12seconds was applied on motor M1.

In the first test run, the system was operated without ES and the results can be seen in Figure 11. The whole load variation is absorbed by the generator.
In the second test run the Enhanced Dynamic Support function is activated and the ES absorbs the full load variation, whilst the generator only supplies the average power of ~60kW.
In the third test-run the generator is intermittently tripped and reconnected and the ES converter moves seamlessly between the spinning reserve and enhanced dynamic support modes. The motor power is unaffected as shown in Figure 13.

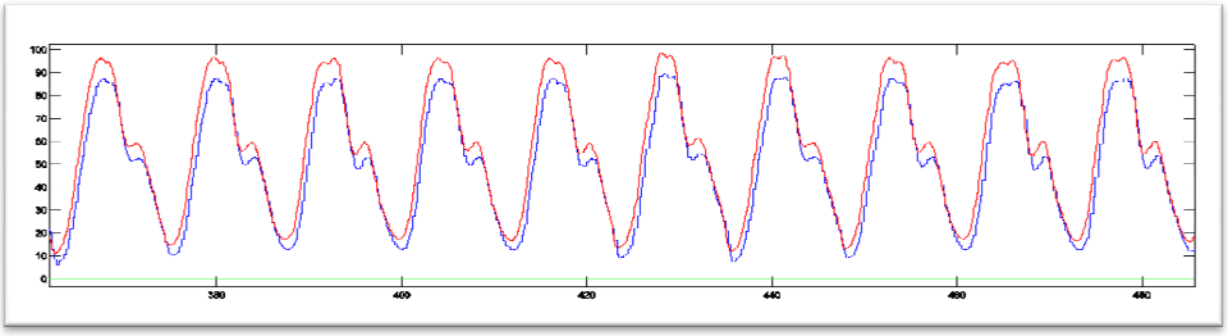

Figure 11 Test Run #1 Blue: Motor Power [kW] Red: Diesel Generator [kW] Green: Battery Power [kW]

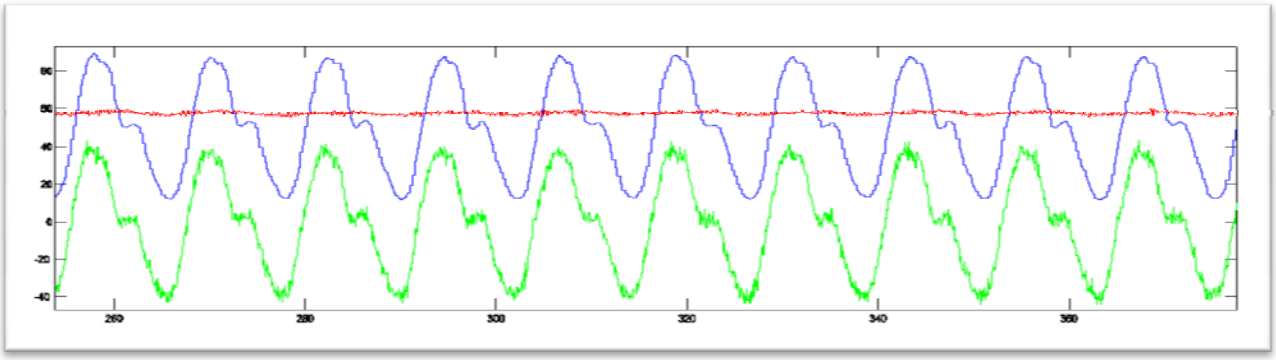

Figure 12 Test Run #2 Blue: Motor Power [kW] Red: Diesel Generator [kW] Green: Battery Power [kW]

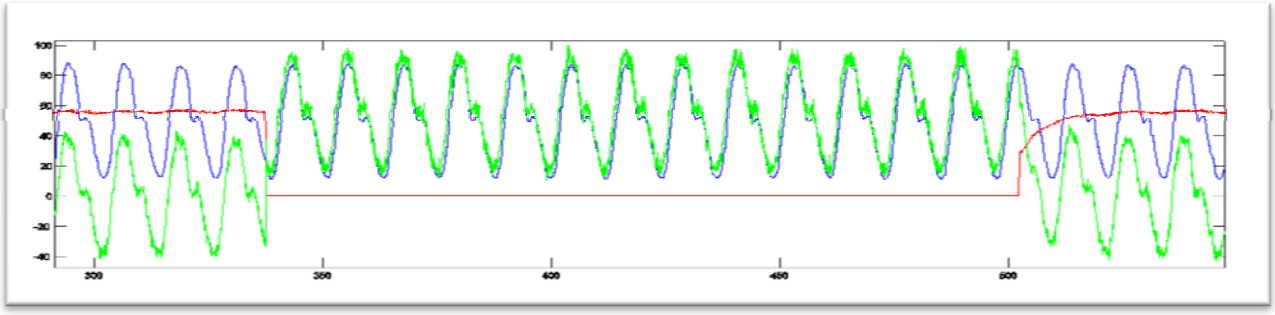

Figure 13 Test Run #3 Blue: Motor Power [kW] Red: Diesel Generator [kW] Green: Battery Power [kW]

Tying it all together

When the established functions of closed-bus operation are adapted and combined with those offered by ES solutions the power system starts taking on a new level of functionality. This section explores the stepwise evolution of a few key maintenance and efficiency parameters as an example drillship power system (Figure 14) evolves from *split system* operation ⇒ *closed ring* operation ⇒ *closed ring* operation with *ES* (Figure 15) using three main operation types as examples.

1) Hoisting 500 short tons @ 3.8ft/sec
2) Lowering 500 short tons @ 3.8ft/sec
3) Drilling with Active Heave
    a. Very high
    b. High
    c. Low
    d. Very Low

These operation types, along with assumptions for each case are described in a more detail in the Appendix.

As described in earlier sections, the industry push for closed bus operation is primarily an operational cost consideration. Retaining the same system dynamic performance, it is possible to operate with fewer generators online. The resulting increase in average generator load and reduced running hours translates into better fuel efficiency and lower maintenance related costs. If ES is added to the mix we observe the same improvement again; a system with a dramatically improved dynamic performance and the possibility of having spinning reserve available at negligible additional operational cost. This means that the engines can be left to supply average load, and ES left responsible for dynamic performance and spinning reserve as this plays to both ES and engine strengths..

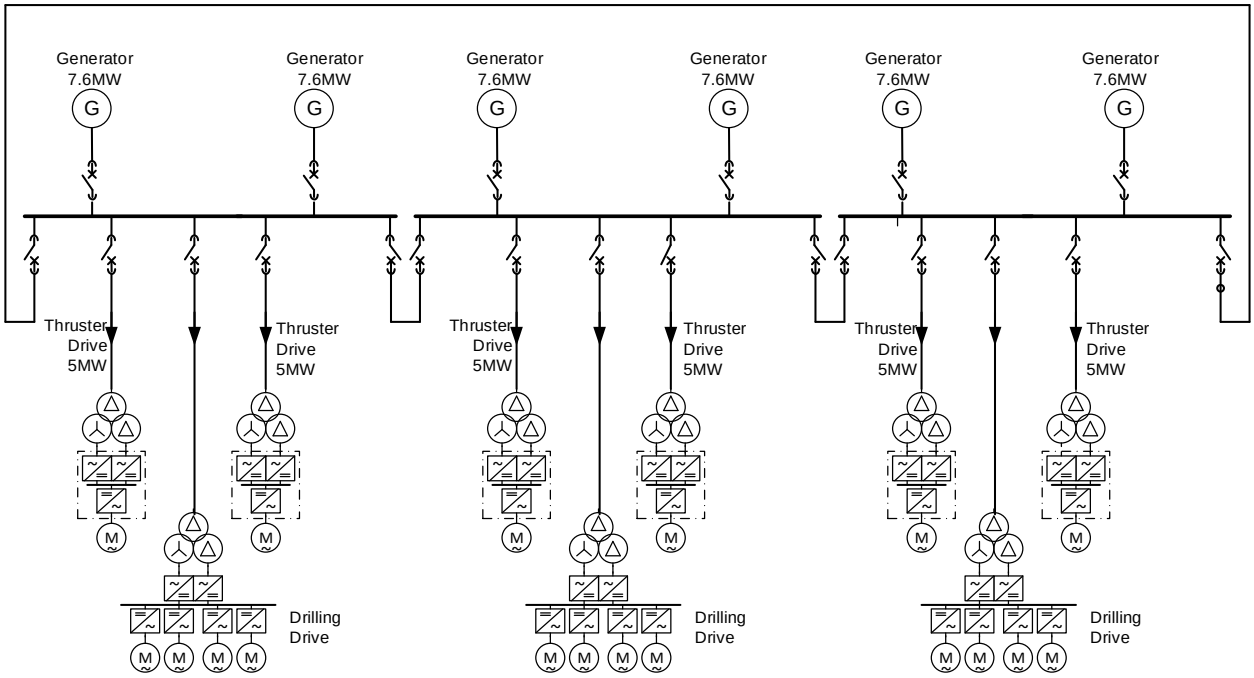

Figure 14 Simple single line representation of reference system

Figure 15 shows how ES is made available both directly in the AC network and in the drilling drive. The former is primarily to meet spinning reserve needs, and the latter to support the dynamic drilling loads

and – when necessary – recover regenerated power from e.g. lowering operations. It also gives the drilling drive a UPS like functionality that could guarantee power to the drilling process even in the event of loss of main supply. It could potentially also replace other mechanical ES devices in the drilling system.

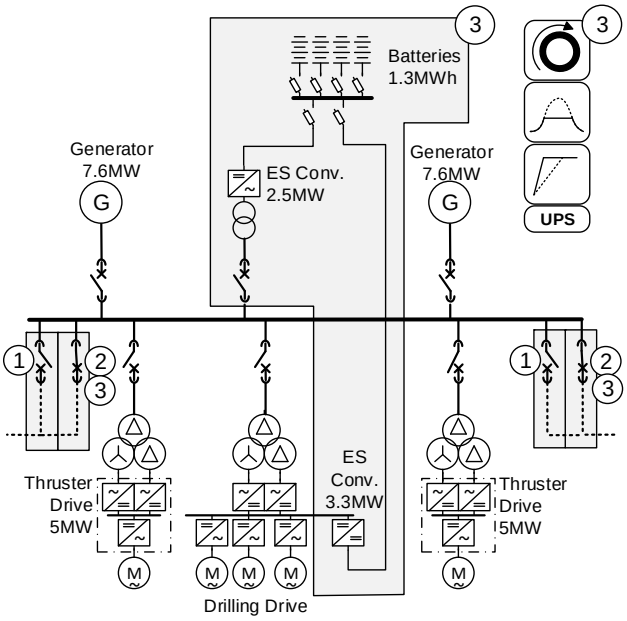

Figure 15 One section of the reference system showing the 3 different system configurations used in the comparison. 1) Open Bus 2) Closed Bus and 3) Closed Bus with ES.

Figure 16 to Figure 18 show how, with a given power demand over time, the ES system can be used to absorb the power fluctuations and let the generator sets supply only the average power.

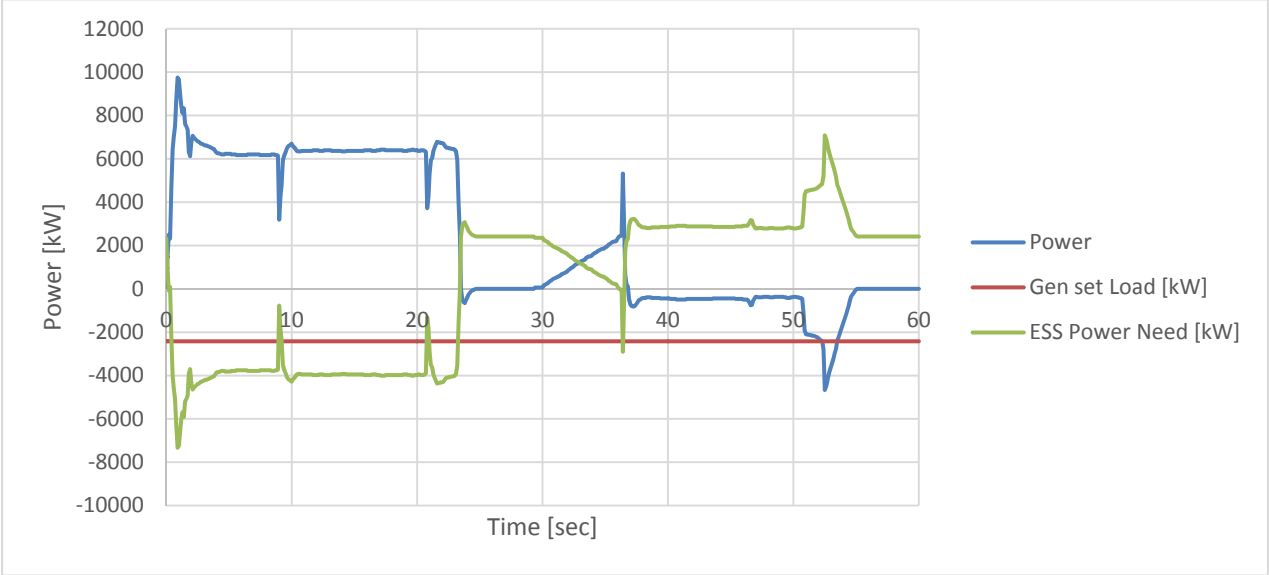

Figure 16 Hoisting with ES

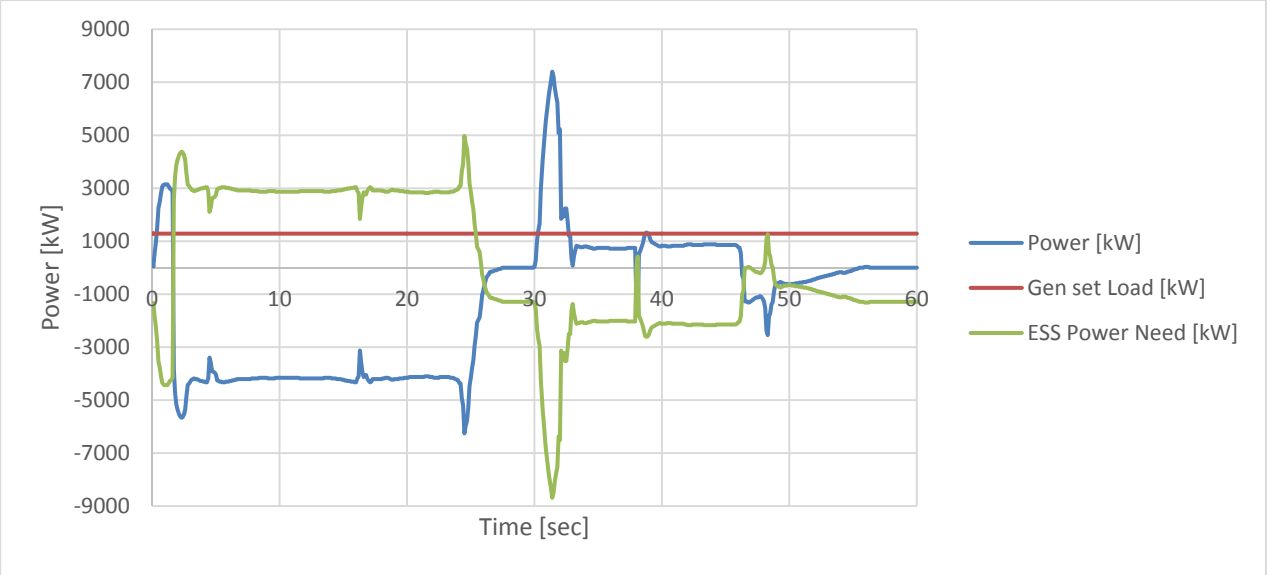

Figure 17 Lowering with ES

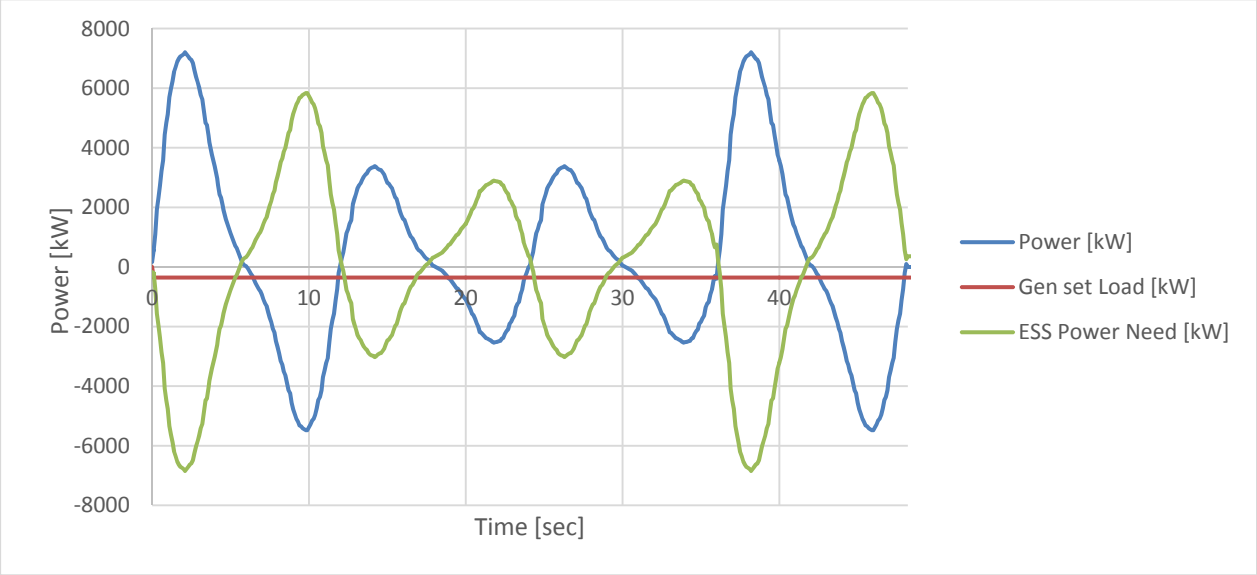

Figure 18 Active heave with ES.

The effect of closed bus operation and the addition of ES can be seen in the bar graphs below.
The closed bus operation has an improved fuel consumption in cases 1,3 and 6 where the specific load situation allowed fewer online generators than the open bus equivalent. ES, on the other hand gives significant reductions across the board. This can be attributed to both being able to run fewer engines than the other two system configurations and the fact that regenerative power is not burned off in a braking resistor, but can be “repatriated” into the system. To put these savings in perspective, the projected savings per 24hr of a given operation are shown in Figure 20.

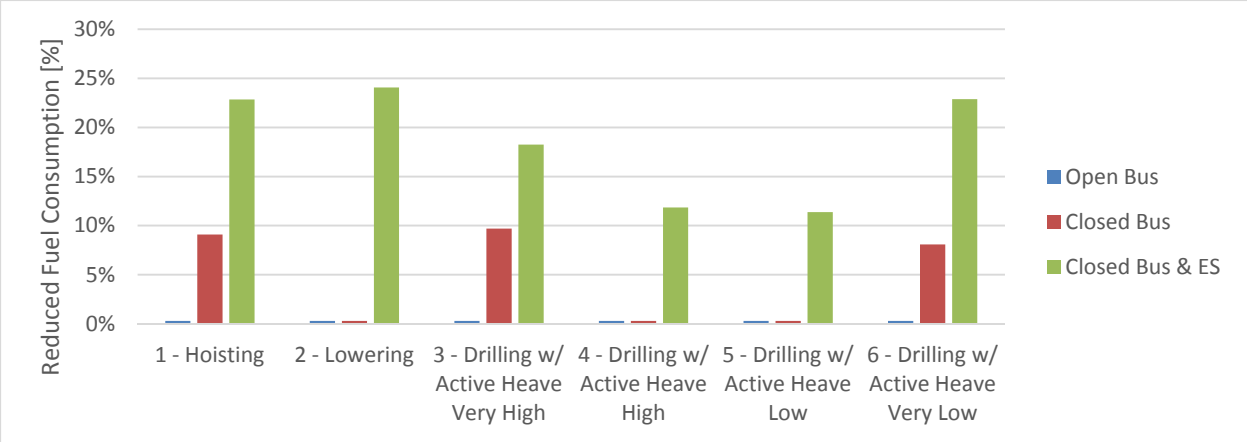

Figure 19 Showing how fuel consumption is reduced with different system configurations and operations.

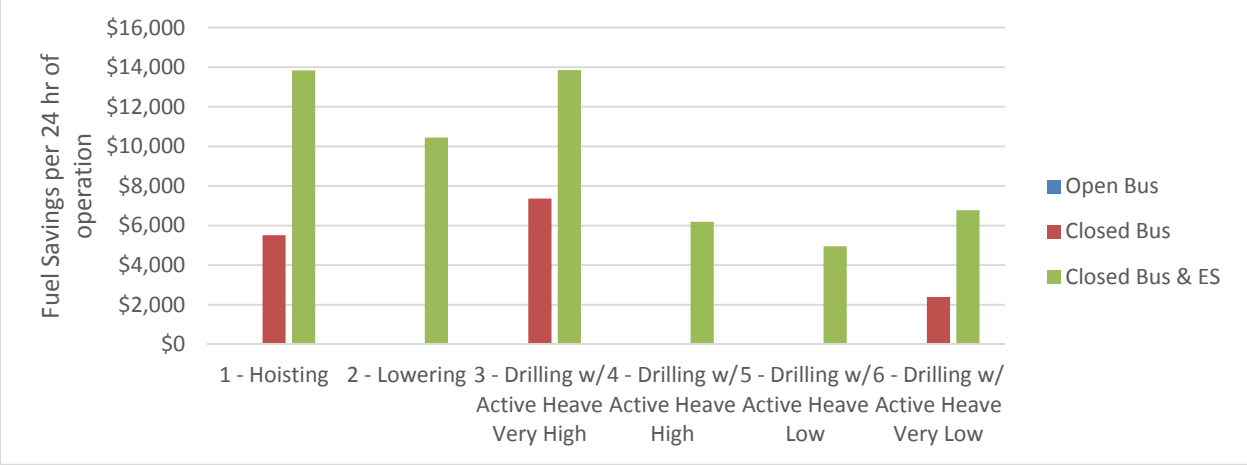

Figure 20 Projected fuel savings over 24hr of given operation using a price of 1000USD/Tonn.

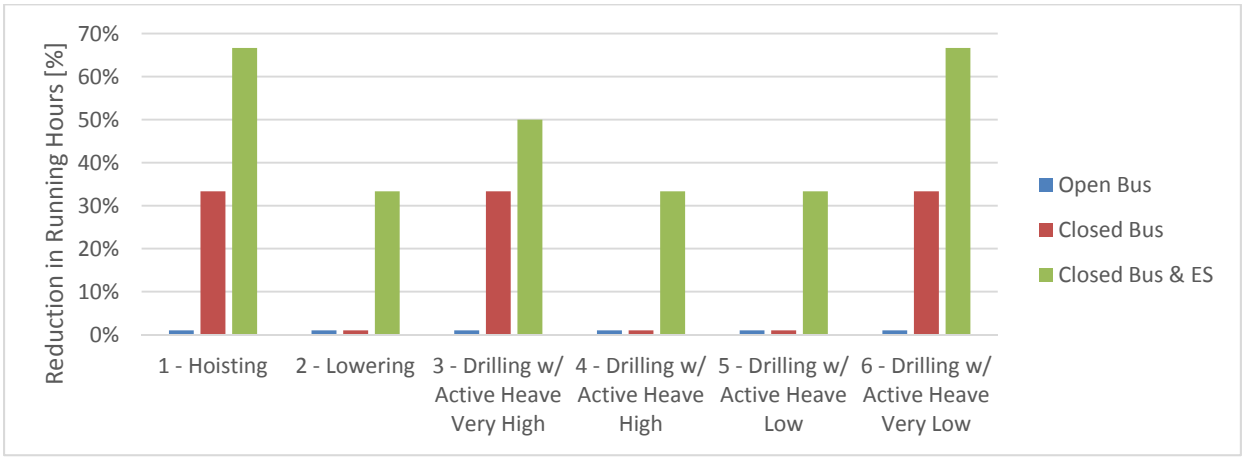

Figure 21 Showing how much running hours can be reduced comapred to open bus operation for different system configurations and operations.

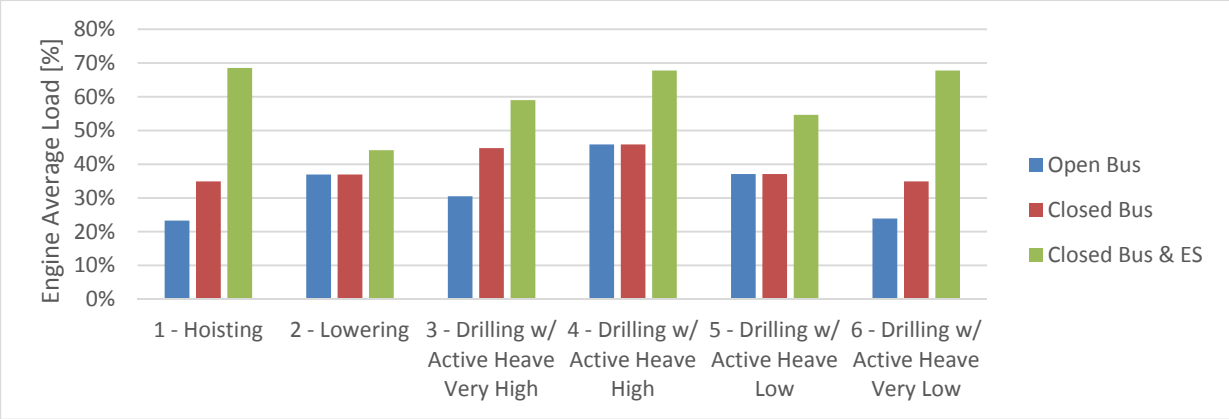

Figure 22 Showing how engine average loading changes with different system configurations and operations.

A similar picture is painted for engine maintenance. Where load picture allows closed bus system to run fewer engines online than open bus equivalent, improved running hour count and average loading are observed. With the addition of ES improvements are seen across the board (Figure 21). Average loading of engines is consistently above the other system configurations, usually by a significant margin, and never falls below 44% (Figure 22). Both of these factors should contribute to a very significant reduction in engine maintenance cost.

Conclusion

In conclusion, the marriage between a comprehensive and flexible protection platform and one or more ES systems has the potential to revolutionize what we will come to expect from diesel electric power systems.

The ES system can fill the function of both a buffer and energy reserve, giving the power system a very significant improvement in dynamic performance and unprecedented system availability. These work together to enable the engines to be run more optimally promising very significant reductions in both fuel and maintenance costs.

References

[1] J. F. Hansen, F. Wendt, J. Jehkonen, J. Varis and L. Tianen, "Improved and Efficient Power and Thruster System for DP Drilling Vessels with New Generation Protection System and Azipod® CZ," MTS Dynamic Positioning Conference, Houston, 2012.

[2] J. F. Hansen, F. Wendt, J. Nowak, K. Hansen and K. Stenersen, "Integrated Power and Automation System for Enhanced Performance of DP Class Drilling Vessels," MTS Dynamic Positioning Conference, Houston, 2013.

[3] DNV, "Dynamic Positioning System with Enhanced Reliability," in *DNV Rules for Classification of Ships; Part 6, Chapter 26*, July 2013.

[4] ABS, "Enhanced Systems," in *Guide for Dynamic Positioning Systems Section 8*, Decemper 2012.

[5] DNV, "8.2.9 Spinning Reserve," in *DNV-RP-E306 Dynamic Positioning - Design Philosophy Guidelines*, September 2012.

Appendix

Case Description

Assumptions and methods

- Sections are loaded equally
- Number of generators online are chosed according to:
  - Generators can accept up to ~30% load steps as required by class. Number of generators is chosen accordingly for the different systems (*Delta Engine Loading* in tables below).
  - Enough spinning reserve must be available to cover base load in case of loss of section/generator. This includes ES for system with ES.
- Draw works are operated at design speed.
- Fuel consumption during dynamic load changes can be estimated using steady-state values shown in Figure 23
- Each battery system is dimensioned to provide 1/3 power of a generator for 30min, and 10MW/3 intermittently to support the drilling operation.

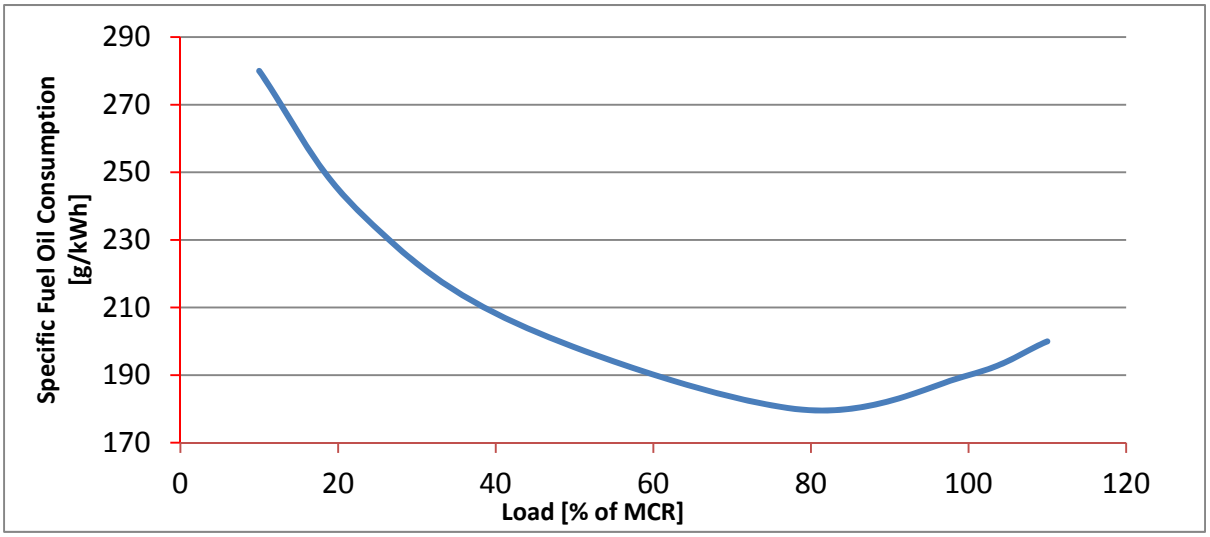

Figure 23 Specific fuel oil consumption of an example medium speed engine as a function of engine load.

Case 1 – Hoisting

	Open Bustie	*Closed Bustie*	*Closed Bustie With ES*
Number engine running	6	4	2
Total Base Load (Thrusters and Aux.) [MW]	8	8	8
Base Load Per Generator [%]	17,5%	26,3%	52,6%
Average Generator Load [%]	23,3%	34,9%	68,5%

Engine Peak Loading [%]	38,9%	58,4%	68,5%
Engine Low Loading [%]	17,5%	26,3%	68,5%
Delta Engine Loading [%]	21,4%	32,1%	0,0%
Reduction in Engine Running Hours [%]	0 %	33 %	67 %
Fuel Consumption per Hour [tones]	2,52	2,29	1,95
Fuel Consumption per Day [tones]	61	55	47
Fuel Cost Saving per Day [$]	0	5 509	13 836
Fuel Cost Saving [%]	0 %	9 %	23 %

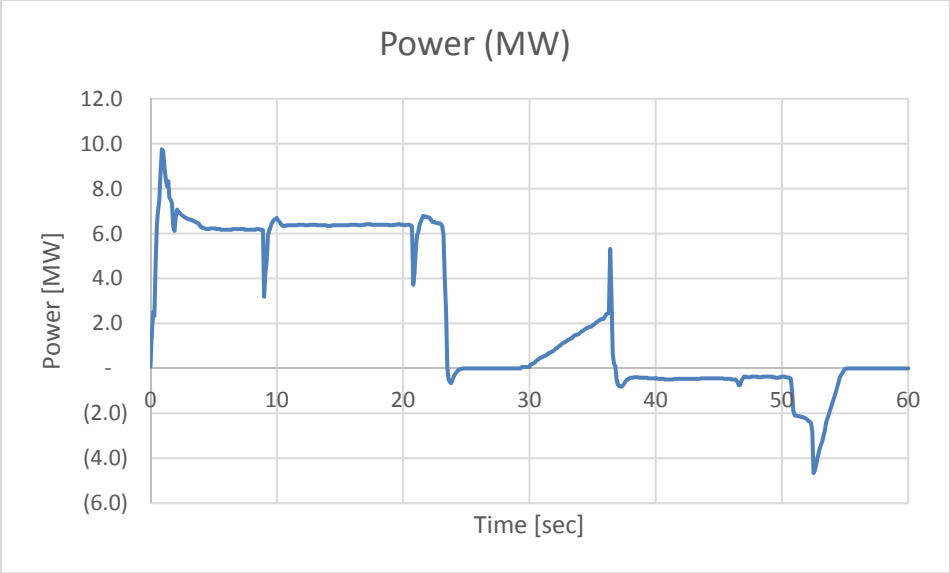

Figure 24 Showing load profile of drilling drive during hoisting of 500 short tons and design speed of 3.8ft/sec

Case 2 – Lowering

Although this case shows load steps in excess of 30%, this steps happens in two stages and was therefore considered acceptable.

	Open Bustie	*Closed Bustie*	*Closed Bustie With ES*
Number engine running	3	3	2
Total Base Load [MW]	8	8	8
Base Load Per Generator [%]	35,1%	35,1%	52,6%
Average Generator Load [%]	37,0%	37,0%	44,2%
Engine Peak Loading [%]	67,5%	67,5%	44,2%
Engine Low Loading [%]	35,1%	35,1%	44,2%
Delta Engine Loading [%]	32,5%	32,5%	0,0%

Reduction in Engine Running Hours [%]	0 %	0 %	33 %
Fuel Consumption per Hour [tones]	1,81	1,81	1,37
Fuel Consumption per Day [tones]	43	43	33
Fuel Cost Saving per Day [$]	-	-	10 445
Fuel Cost Saving [%]	0 %	0 %	24 %

Figure 25 Showing load profile of drilling drive during lowering of 500 short tons and design speed of 3.8ft/sec

Case 3 – Drilling with Active Heave

In the drilling with active heave scenario 4 levels were considered

1) Very high – Load profile as shown in Figure 26 scaled down to 87,5% with base load of 13MW.
2) High – Load profile as shown in Figure 26 scaled down to 62,5% with base load of 10MW.
3) High – Load profile as shown in Figure 26 scaled down to 37,5% with base load of 8MW.
4) High – Load profile as shown in Figure 26 scaled down to 12,5% with base load of 5MW.

System Configuration code used in table

1) Open Bus
2) Closed Bus
3) Closed Bus with ES

	Very High			*High*			*Low*			*Very Low*		
System Configuration	1	2	3	1	2	3	1	2	3	1	2	3
Number engine running	6	4	3	3	3	2	3	3	2	3	2	1
Total Base Load [MW]	13	13	13	10	10	10	8	8	8	5	5	5
Base Load Per Generator [%]	29 %	43 %	57 %	44 %	44 %	66 %	35 %	35 %	53 %	22 %	33 %	66 %
Average Generator Load [%]	31 %	45 %	59 %	46 %	46 %	68 %	37 %	37 %	55 %	24 %	35 %	68 %
Engine Peak Loading [%]	42,3%	63,5%	58,4%	63,6%	63,6%	67,3%	46,9%	46,9%	53,5%	25,9%	38,8%	66,4%
Engine Low Loading [%]	28,5%	42,8%	58,4%	43,9%	43,9%	67,3%	35,1%	35,1%	53,5%	21,9%	32,9%	66,4%
Delta Engine Loading [%]	13,8%	20,7%	0,0%	19,8%	19,8%	0,0%	11,9%	11,9%	0,0%	4,0%	5,9%	0,0%
Reduction in Engine Running Hours [%]	0 %	33 %	50 %	0 %	0 %	33 %	0 %	0 %	33 %	0 %	33 %	67 %

Fuel Consumption per Hour [tones]	3,16	2,86	2,58	2,18	2,18	1,92	1,81	1,81	1,61	1,23	1,13	0,95
Fuel Consumption per Day [tones]	76	69	62	52	52	46	44	44	39	30	27	23
Fuel Cost Saving per Day [$]	-	7 360	13 849	-	-	6 188	-	-	4 957	-	2 393	6 769
Fuel Cost Saving [%]	0 %	10 %	18 %	0 %	0 %	12 %	0 %	0 %	11 %	0 %	8 %	23 %

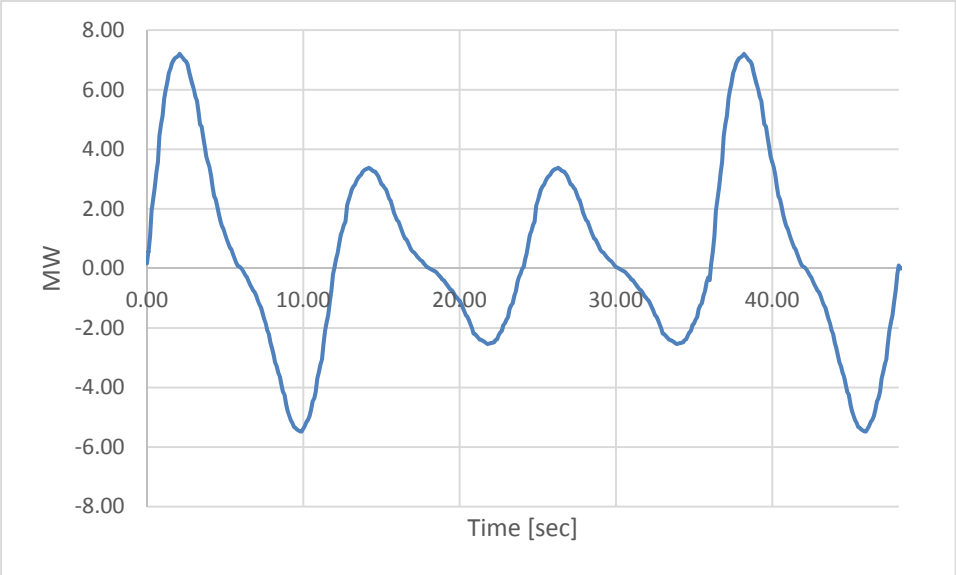

Figure 26 Drilling Active Heave profile.