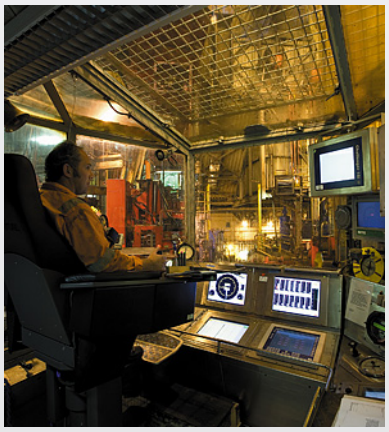
AADE
AMERICAN ASSOCIATION of DRILLING ENGINEERS

Transocean

Your Next Generation Driller

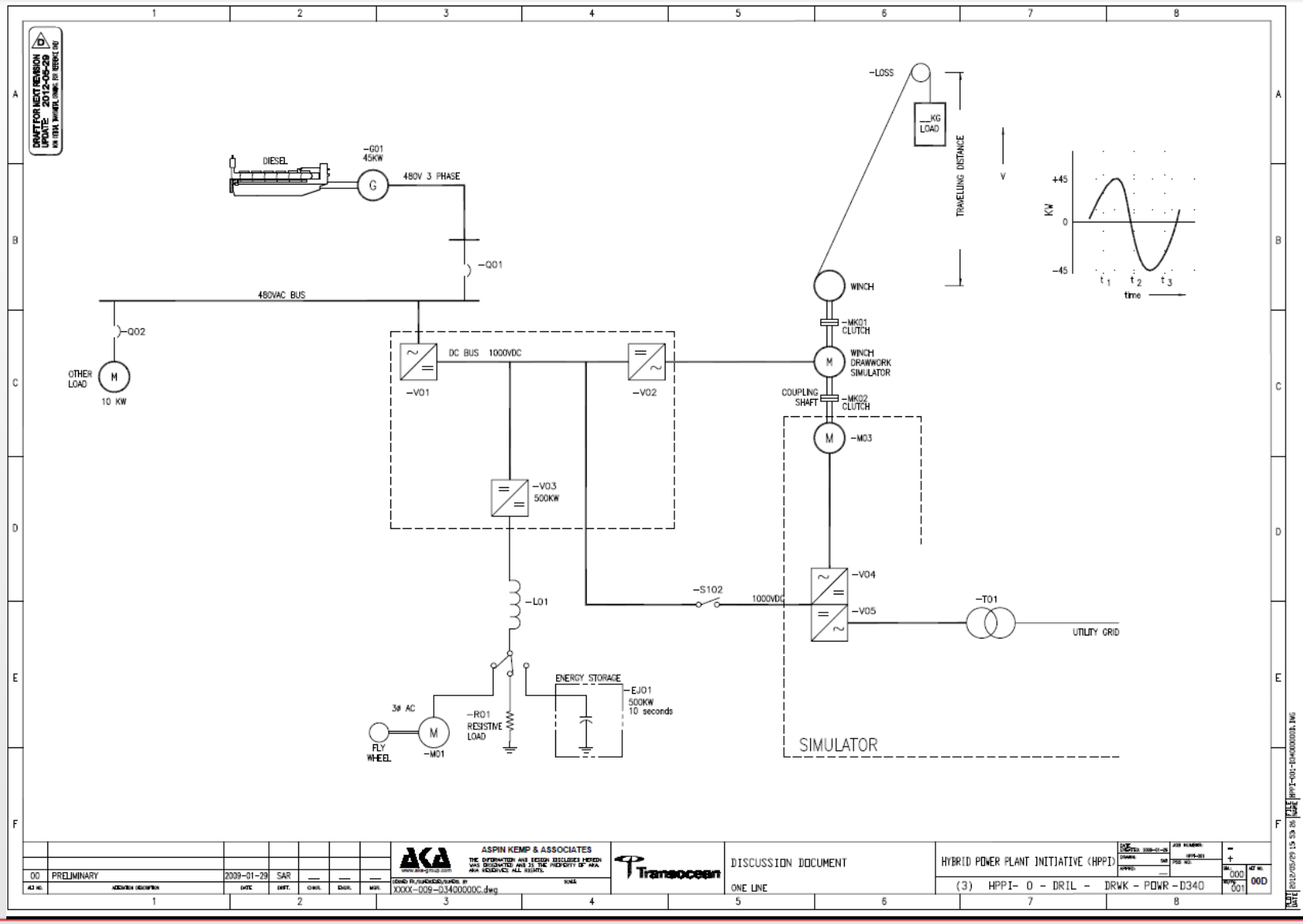
A Practical Application of Hybrid Power Technology to a Modern Drill Floor

24 Mar 2016 Houston
Dr. Yin Wu



Hybrid Power Initiative

- What is Hybrid Power?
  - multiple power sources to power the process loads
  - different technologies
    - ✓ mechanically coupled diesel engine generator sets
    - ✓ Batteries
    - ✓ ultra-capacitors
    - ✓ kinetic energy stored in moving mass, etc.
- Why did Transocean design and patent the hybrid power plant - Active Power Compensation?
  - the use of the conventional continuous power with cyclical load results in inefficiencies, which is in conflict with diesel emission reduction
  - Transocean's Dual Activity Draw-works doubles the aggressive load, the power plant has to be oversized to accommodate peak load


DRAFT FOR NEXT REVISION
UPDATE: 2012-05-29
DIESEL
-G01
45KW
480V 3 PHASE
-Q01
480VAC BUS
-Q02
OTHER LOAD
10 KW
DC BUS 1000VDC
-V01
-V02
-V03
500KW
-L01
-S102
1000VDC
-V04
-V05
-T01
UTILITY GRID
ENERGY STORAGE
-EJ01
500KW
10 seconds
3ø AC
-R01
RESISTIVE LOAD
FLY WHEEL
-M01
-LOSS
KG LOAD
TRAVELLING DISTANCE
WINCH
-MK01
CLUTCH
WINCH DRAWWORK SIMULATOR
COUPLING SHAFT
-MK02
CLUTCH
-M03
+45
0
-45
KW
time
SIMULATOR
ASPIN KEMP & ASSOCIATES
DISCUSSION DOCUMENT
ONE LINE
HYBRID POWER PLANT INITIATIVE (HPPI)
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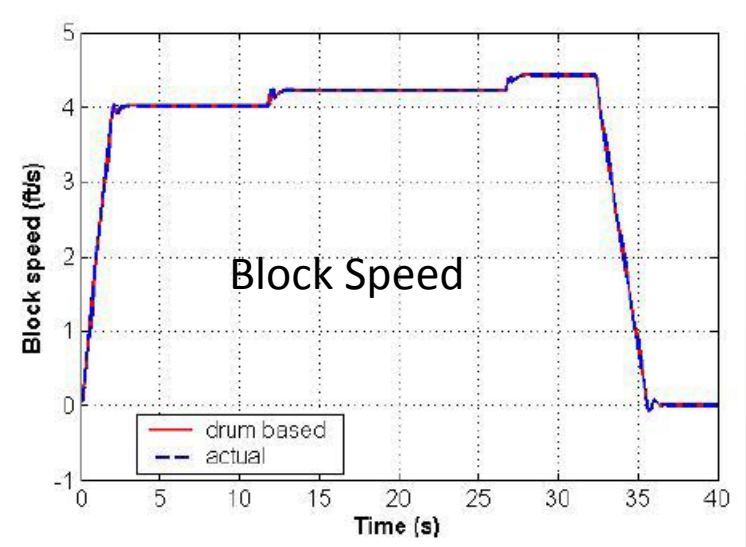
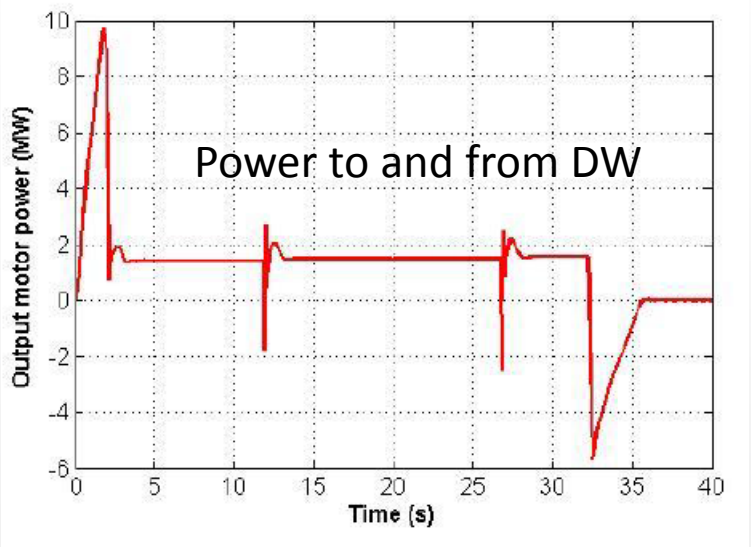
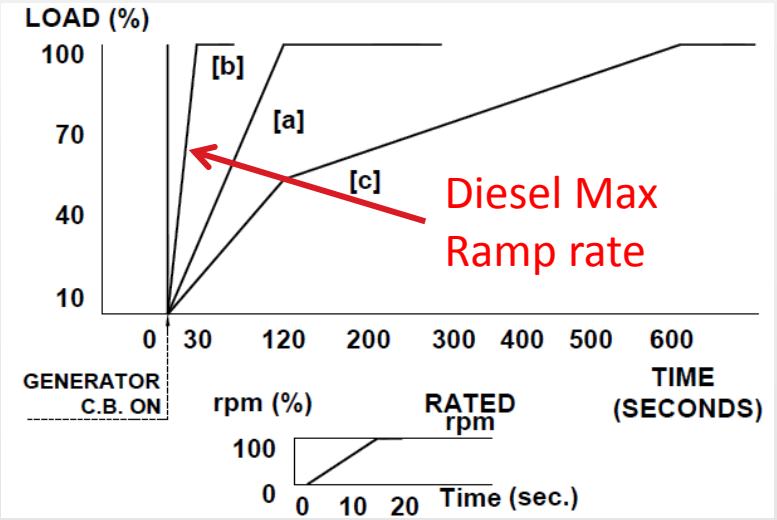
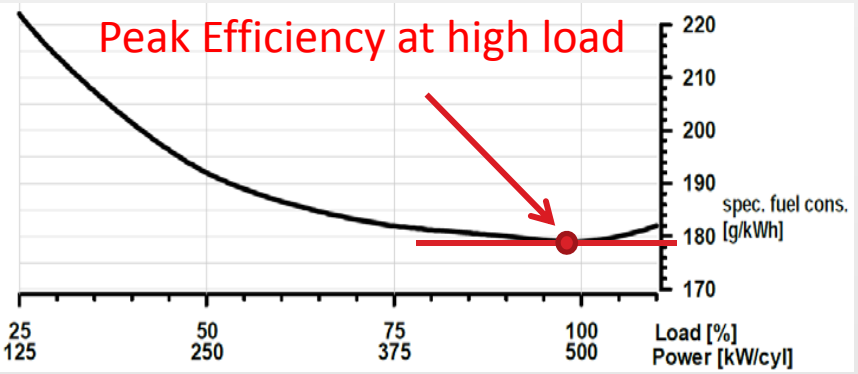


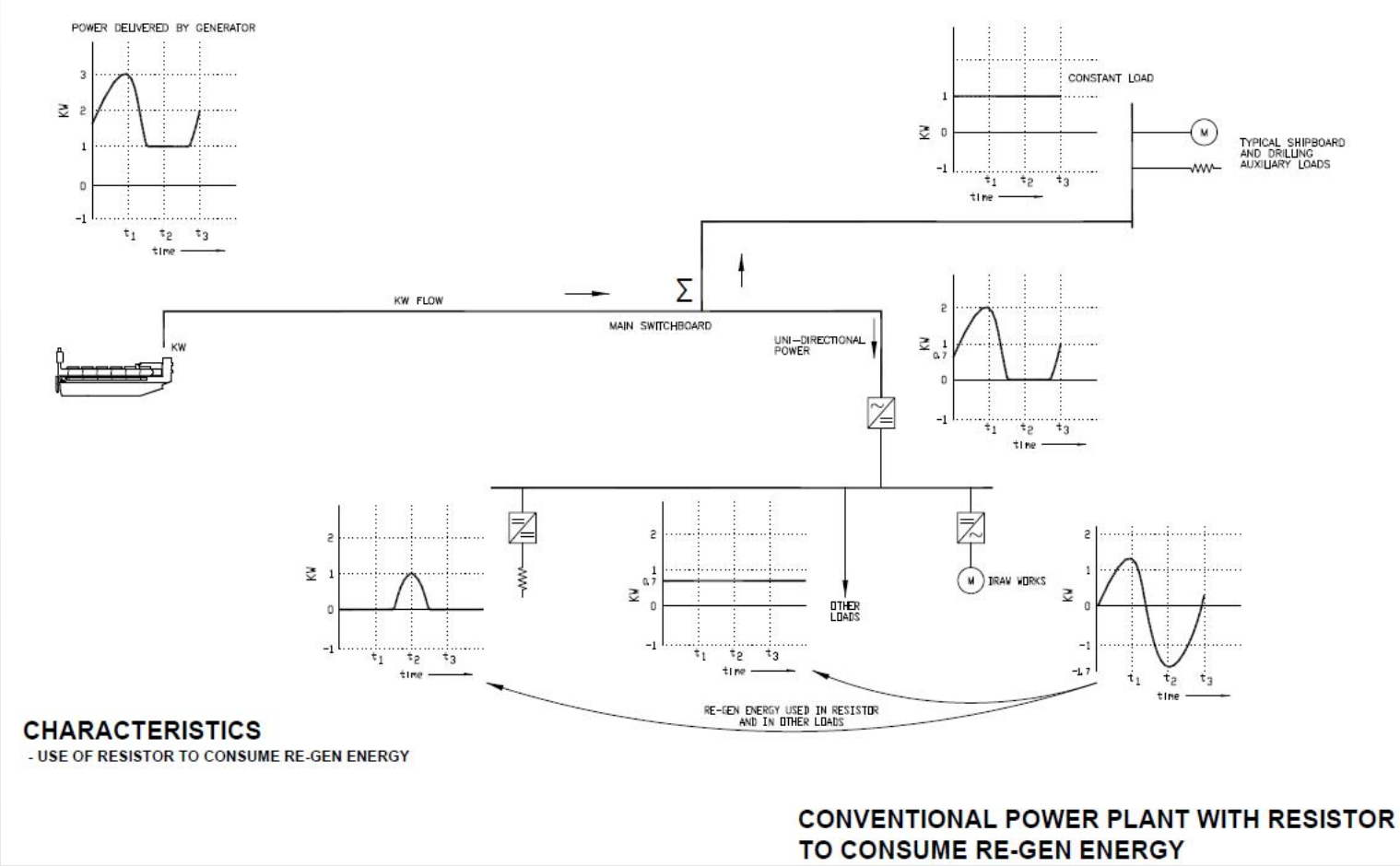






Diesel Efficiency

- **Customers expect improved fault tolerance through the entire drilling process**
- **Drawworks dynamic load profile requires energy regeneration**



CONVENTIONAL POWER PLANT WITH RESISTOR TO CONSUME RE-GEN ENERGY

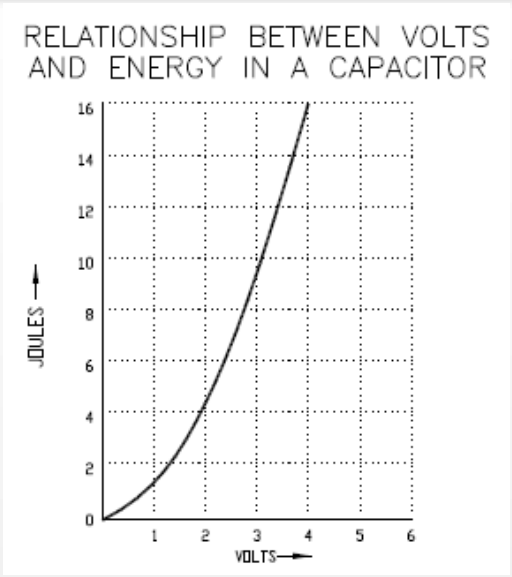
Energy Storage Technologies

- Chemical storage – Batteries
- Magnetic field storage – Super cooled inductors
- Mechanical storage – Rotating masses
- Electrical field storage – Ultra-capacitors

Ultra Capacitor

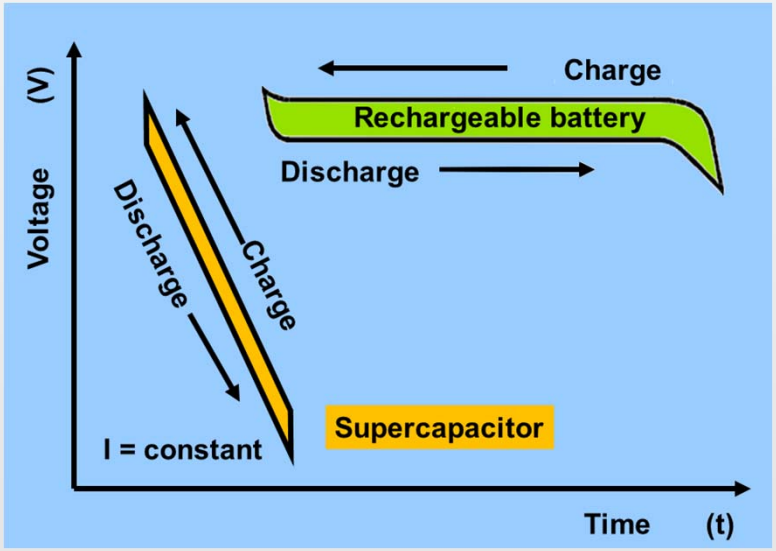
125V, 63F, 500 Kilojoules

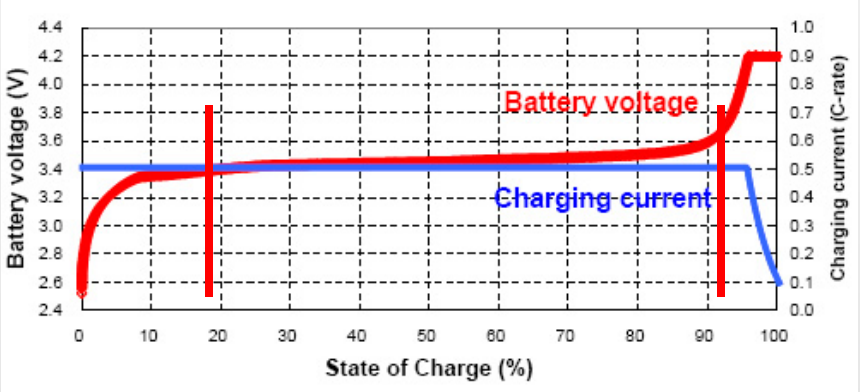
- **Batteries**
  - **High energy density**
  - **Difficult to monitor the state of charge**
  - **Difficult for complete discharge**
- **Ultra-capacitors**
  - **High power density**
  - **Easy to monitor by checking voltage**
  - **Capable of complete discharge**



$$E = \frac{1}{2}CV^2$$

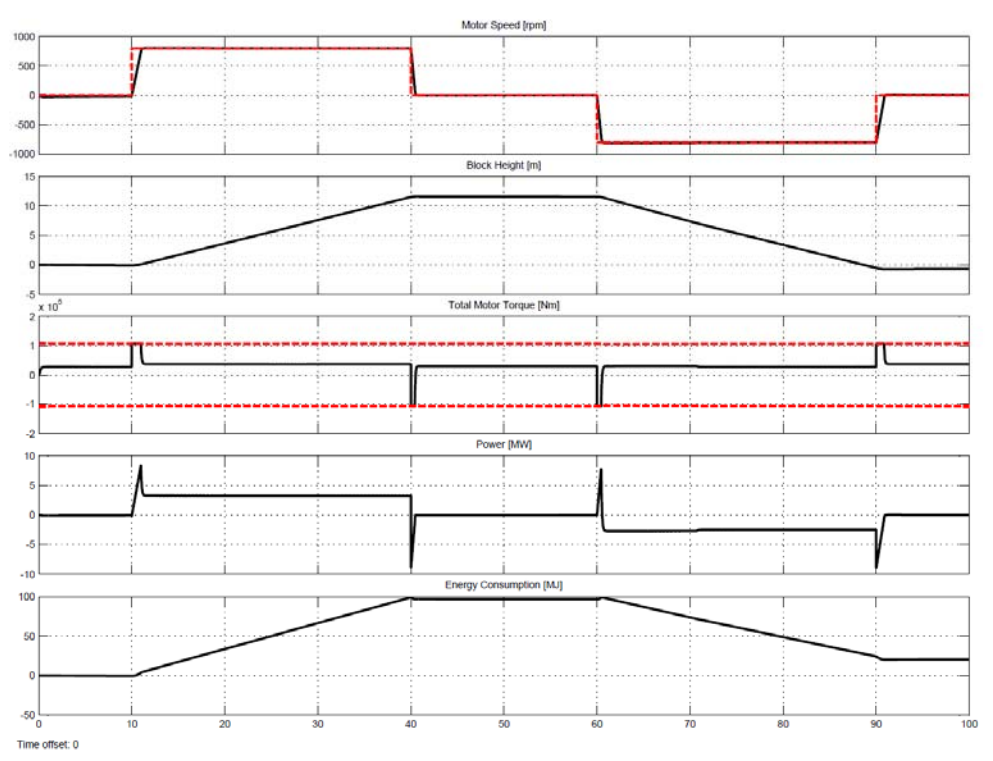
Large voltage variation vs. stored energy





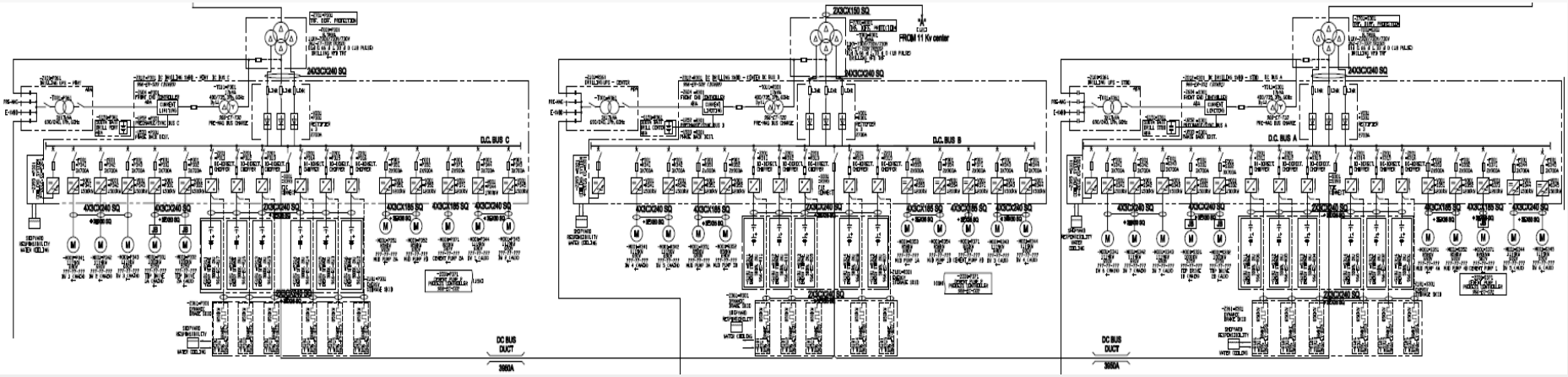
Very little voltage variation vs. stored energy

- **How to dimension the energy storage system?**
  - **The total volume of energy in Joules**
  - **The power requirement, how fast is the energy moved**



Simulation of 1400 tons Drawworks on Deepwater Thalassa

- **Tolerance of failure**

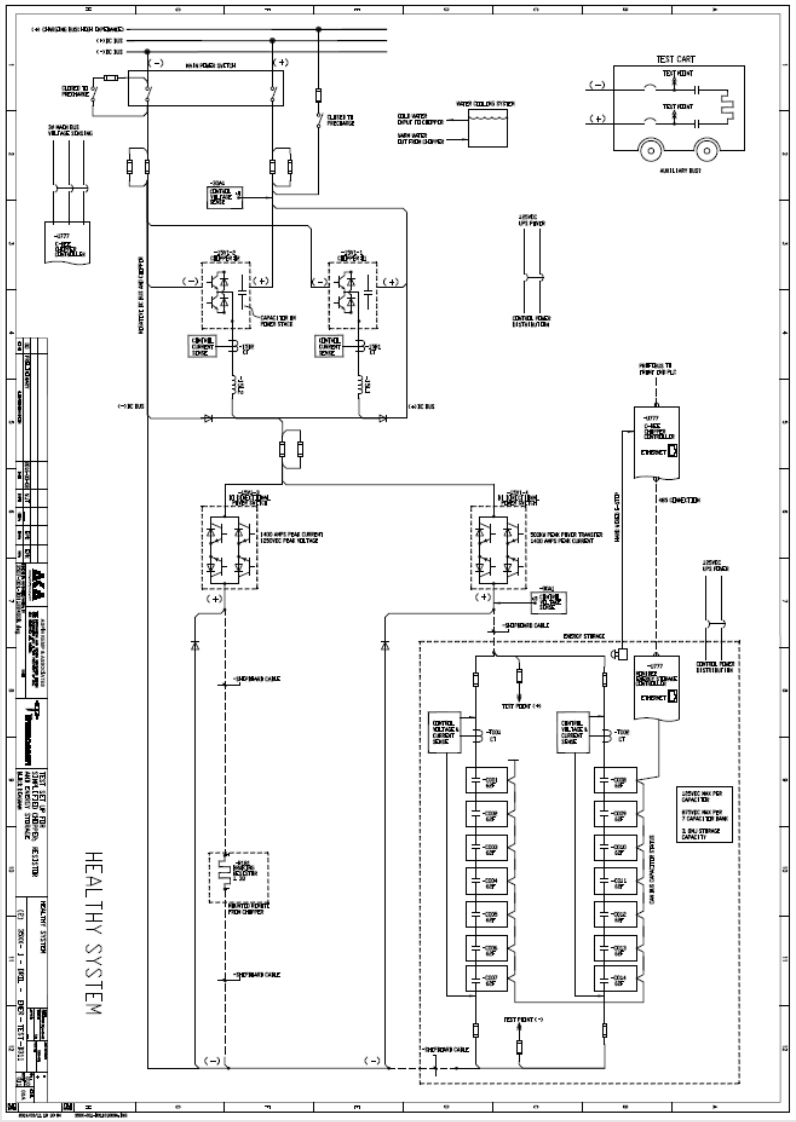


[Deepwater Thalassa One-Line Diagram]

- **Use existing infrastructure**
  - **DC bus**
  - **Braking resistor**
  - **Bi-directional DC/DC current regulated converter**

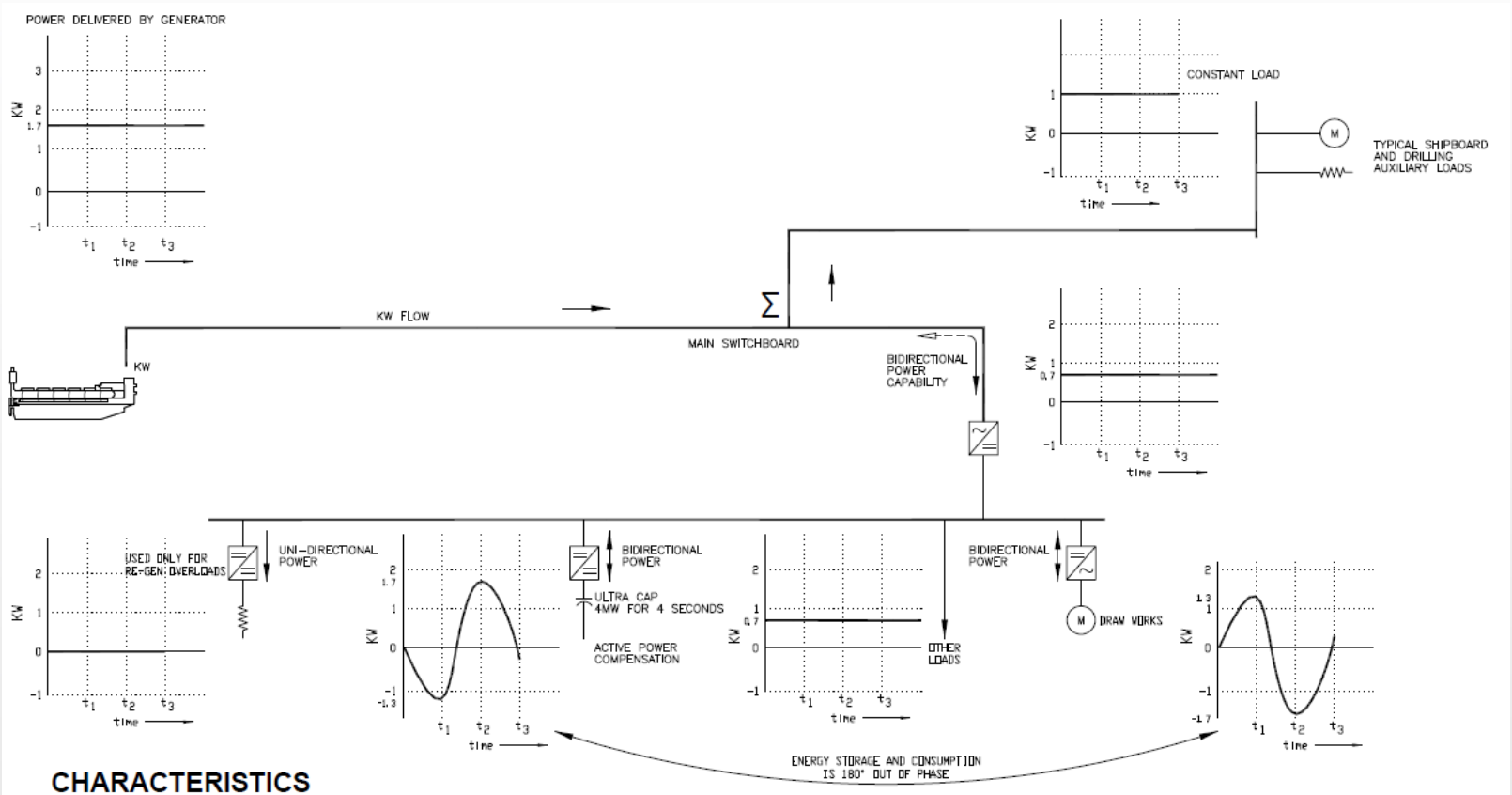
Deepwater Thalassa One-Line Diagram

One typical Energy Storage and Power Dissipation Unit



Control System

- The objective of energy storage system is to respond to power plant stress, not to a particular load
- Objectives of Energy storage and power dissipation unit
  - Momentary fault ride through capability
  - Active power compensation – “dip filling”, “peak shaving”
  - Operation during “black out”
- Task of the control system
  - Control the charge or discharge of the energy storage units
  - Discharge DC bus - dissipation of power into either capacitor or resistor
  - Safety function – turn off the system and removal of energy from the energy storage units



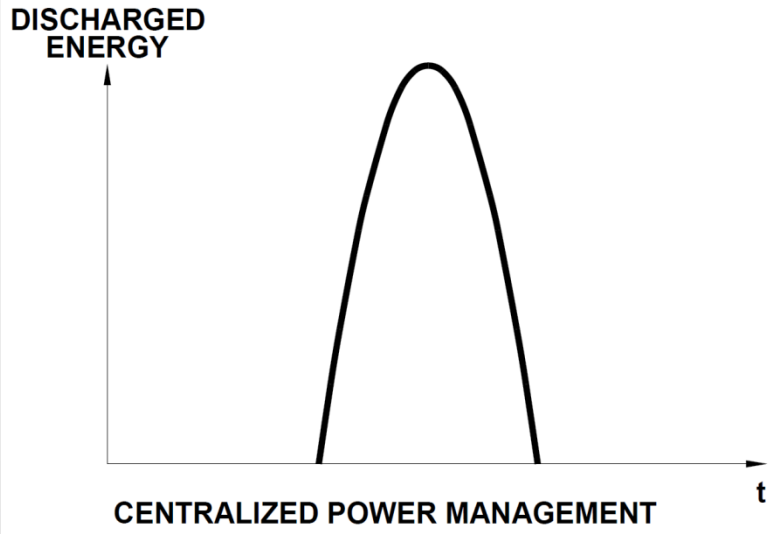
CHARACTERISTICS

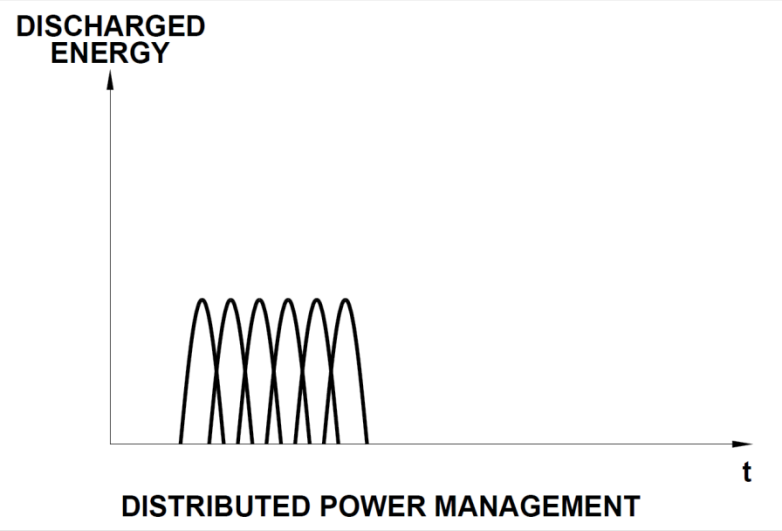
- USE OF RESISTOR ONLY FOR OVERLOADS.
- USE OF STORED ENERGY TO RUN CYCLICAL LOADS
- USE OF STORED ENERGY TO REGULATE AC BUS.

HYBRID POWER PLANT WITH ACTIVE POWER COMPENSATION SYSTEM

- **Autonomous control system**
  - **Important for FMEA (Failure Mode Effect Analysis)**
  - **Centralized controller adds complexity and becomes unpredictable**
  - **Divide system into 17 units, only 1/17 of system is lost on one single failure**
  - **A controller that is autonomous to every storage and power dissipation unit**
  - **Each unit monitors the infrastructure to decide whether to charge or discharge**
  - **The infrastructure also activates the safety functions to either shut down or discharge into resistor**
    - ✓ **DC bus voltage**
    - ✓ **Main 11KV bus frequency**
    - ✓ **Main 11KV bus voltage**
  - **Other infrastructure factors: Cooling water health, Resistor health, Capacitor health**

- **Load sharing**
  - **The control system doesn't respond on load sharing simultaneously.**
  - **Coverage of a broad spectrum of responses, by programming each controller with slight differences**
  - **Each individual unit responds naturally after the other units' action**
  - **Synchronize all 17 units at the same speed, when performing test**

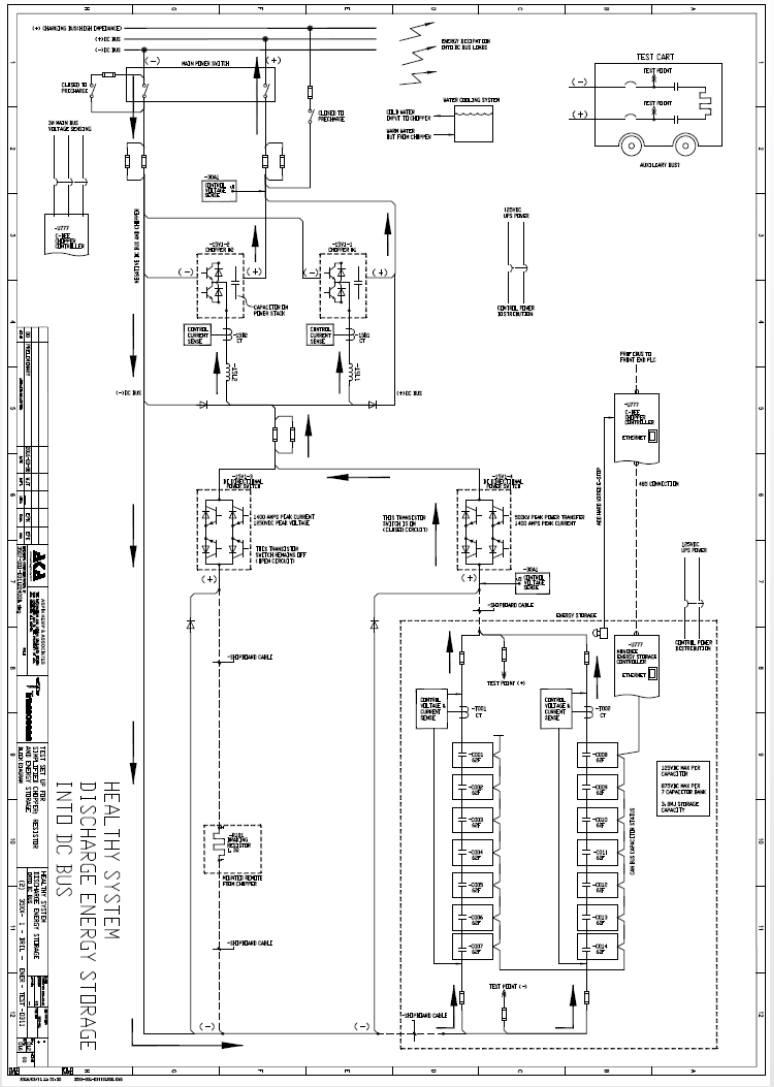




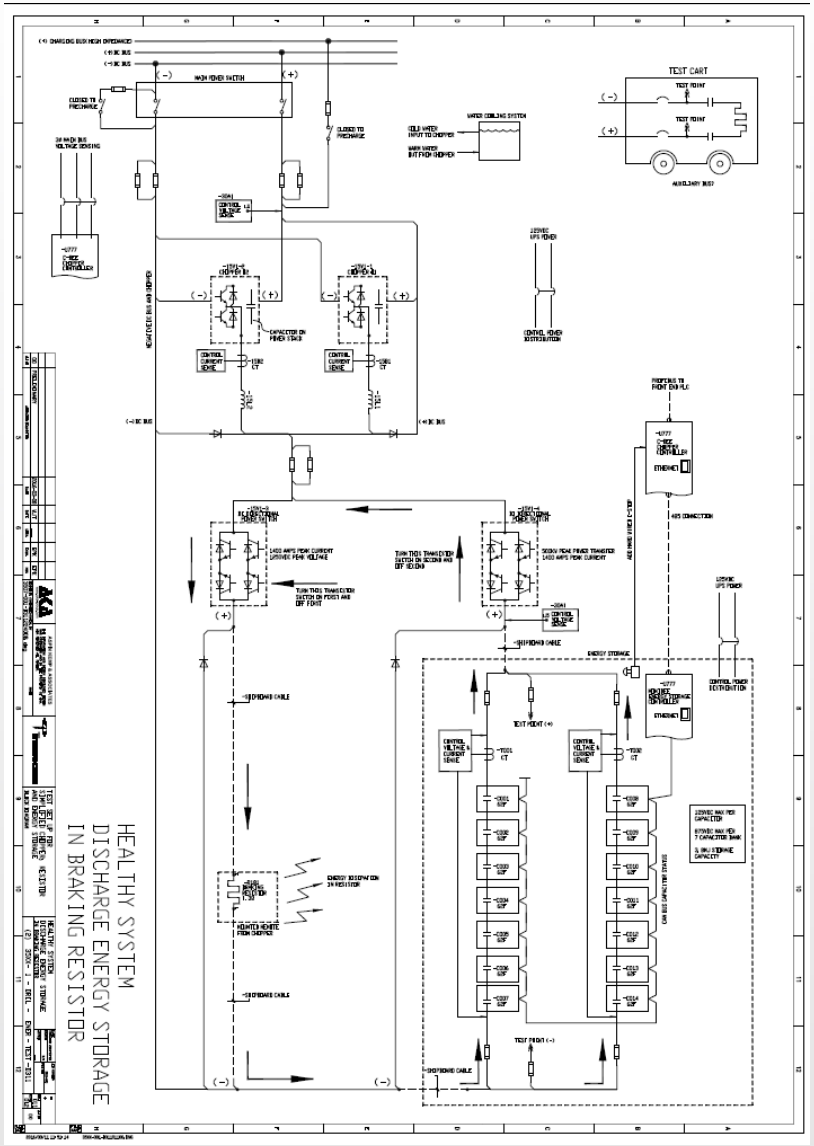
Safety Cases

- Risk assessment was the foundation to understand the safety cases
- Uncontrolled release of energy
  - External faults can be interrupted by fuses
  - Fault inside the energy storage unit
- Prevention (measures to prevent a risk event from happening)
  - Keep 17 units relatively segregated in separate cabinets
  - Prevent cable short circuit – extra-insulation, short run of cables, mechanical protection
- Mitigation (measures to limit the effect of a risk event)
  - Reducing the size of energy storage units
  - Fuses protect the cables and stop the uncontrolled release of energy
  - Temperature monitoring

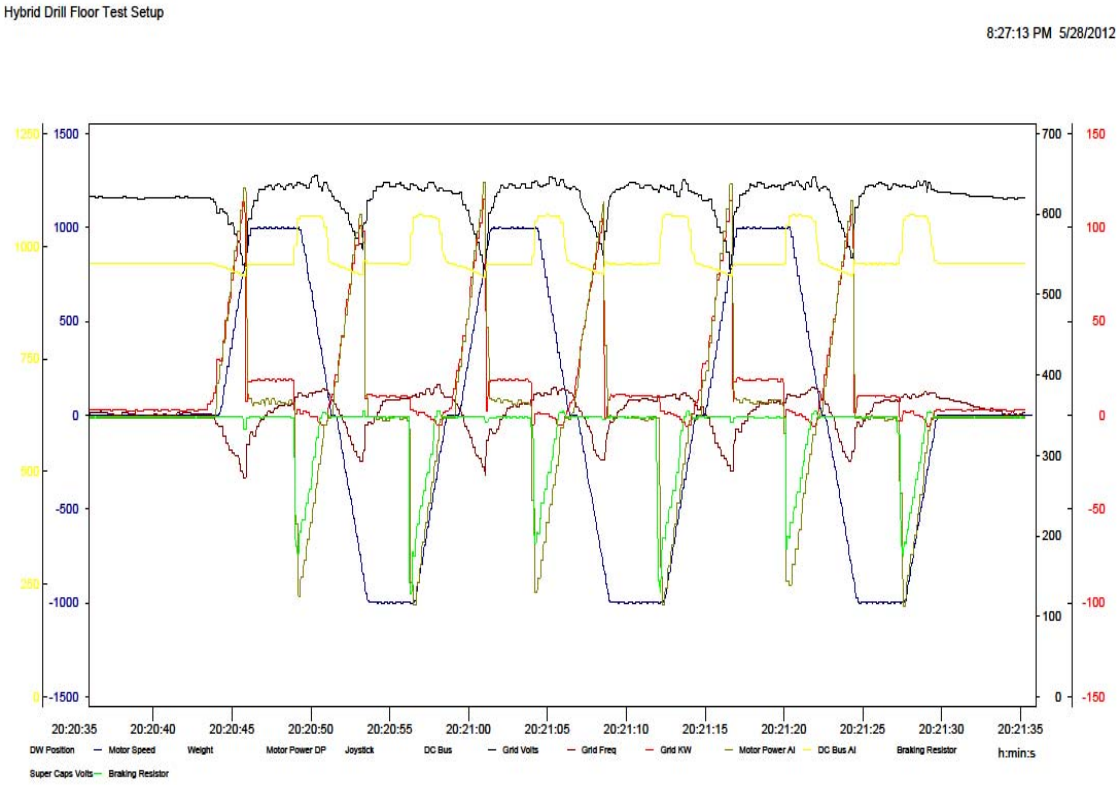
- **Strategy to remove energy from the energy storage units**
  - **Emergency shut-down should not discharge energy storage units**
  - **Discharge into the DC bus**



- **Discharge through the braking resistors**
- **Manual discharge by connecting a conductor directly via test points**



Plant with out energy storage. Braking energy is in GREEN



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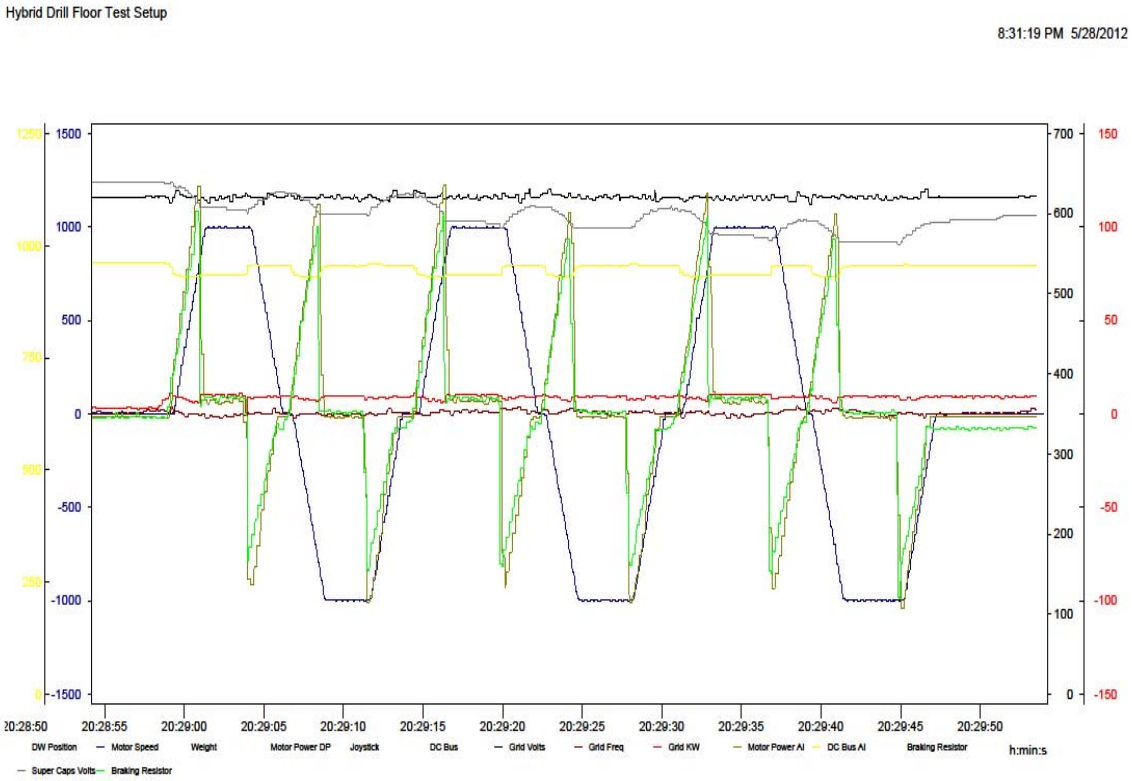
This graph show generator power in red, jumping to a peak and then falling to steady state and then zero before jumping again.

Plant WITH energy storage. GREEN is energy in and out of Energy storage.



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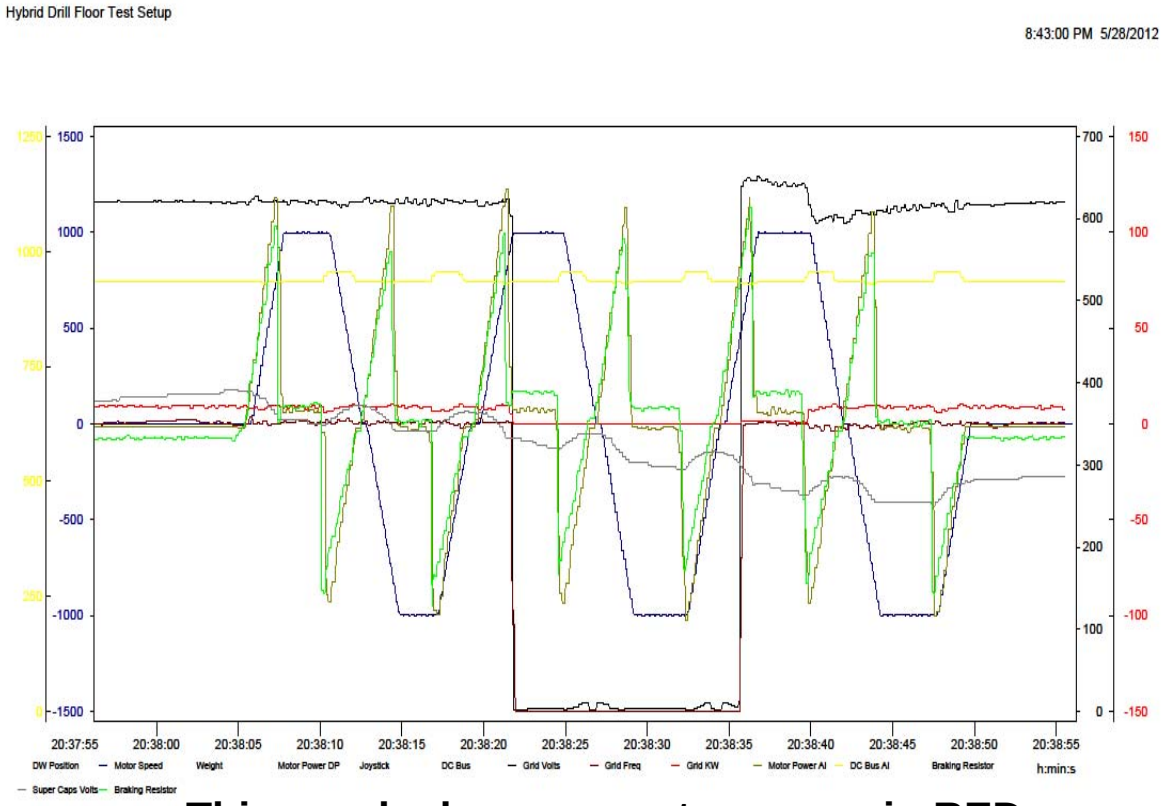
This graph show generator power in RED A steady power flow even with Draw-works raising and lowering.

Plant WITH energy storage. GREEN is energy in and out of Energy storage.



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This graph show generator power in RED. With Generator completely OFF for 15 seconds, (Blackout) the Draw-works is still raising and lowering.

Hybrid Drill Floor Test Setup

Plant WITH energy storage. GREEN is energy in and out of Energy storage.

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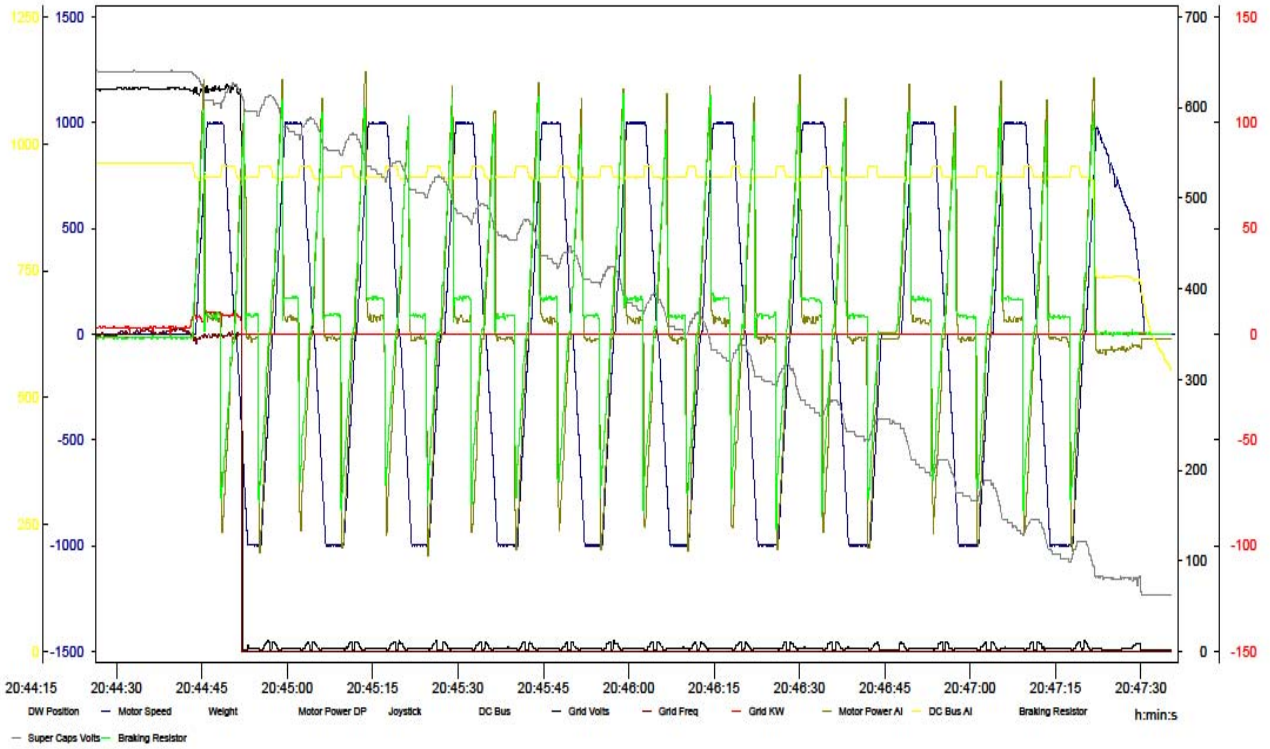

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This graph show generator power in RED. With Generator completely OFF (Blackout) the Draw-works operates and energy storage (GREY) is used and recharged until finally exhausted.

- Video using diesel generator as the only energy source
- Video using hybrid power system

Summary

- For practical application of hybrid power, we reviewed
  - What is hybrid power? Why TOI developed and patented the hybrid power?
  - How to dimension energy storage system?
  - Control system review
  - Safety cases review
  - Practical examples

Thanks !