Dredge Machinery – Innovative Rotary Drives

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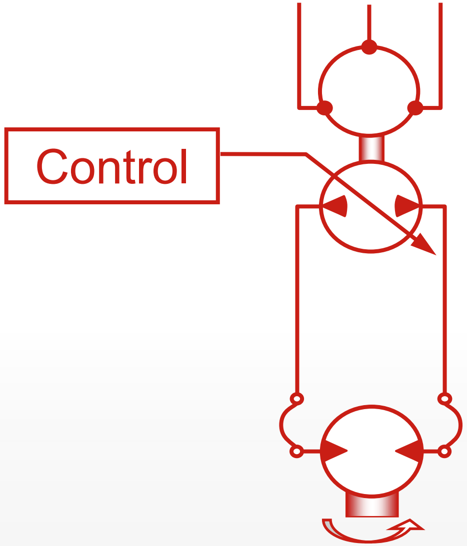
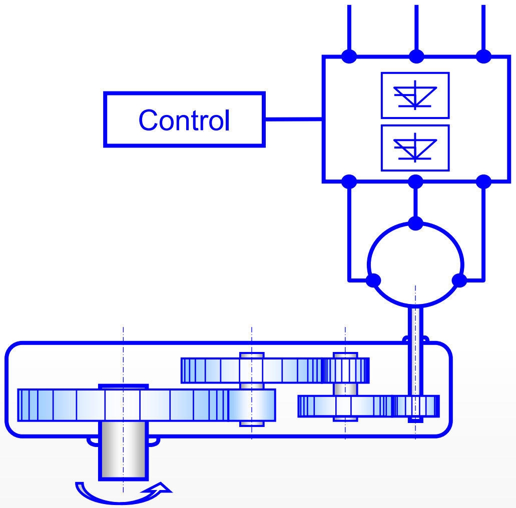
Machines drive Dredges

Hydraulics vs Electrics

Electric and hydraulic circuits are similar in principle

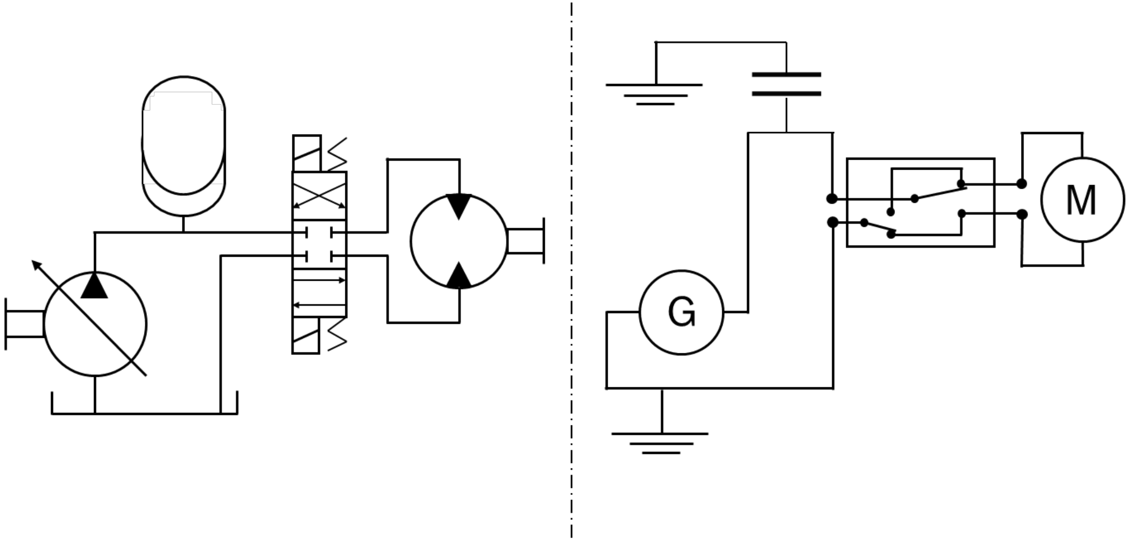
- Pressure difference p is equivalent to voltage U
- Flow Q is equivalent to current I





Hydraulics vs Electrics

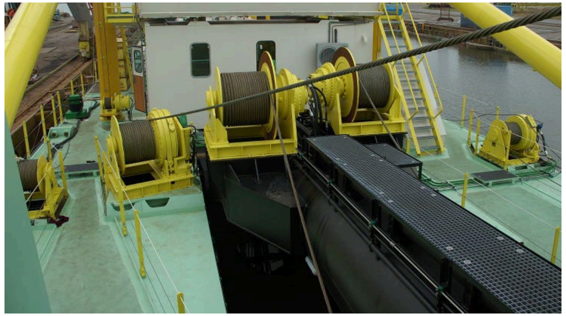
Hydraulic system components have electric counterparts

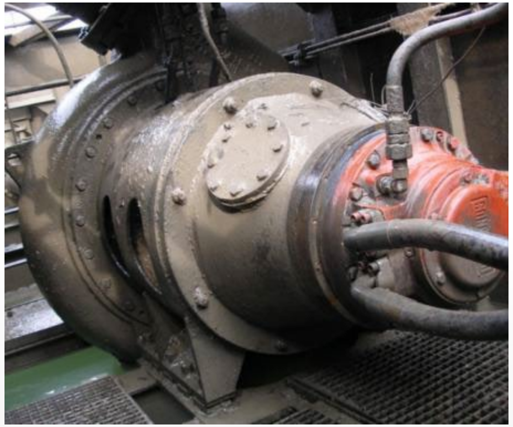


- Pumps are equivalent to Generators
- Cylinders are equivalent to Linear Actuators
- Hydraulic Motors are equivalent to Electric Motors
- Accumulators are equivalent to Batteries and Capacitors
- Valves are equivalent to Switches and Resistors

Rotary Actuators in Dredges

- Winch drives
- Cutter Suction head
- Dredge (Sand) pump
- Thrusters, propulsion



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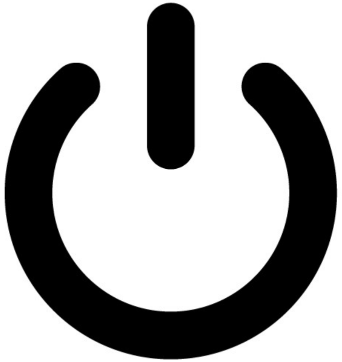
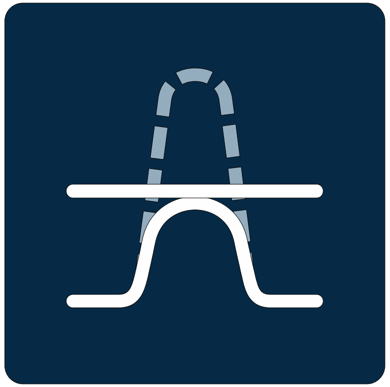
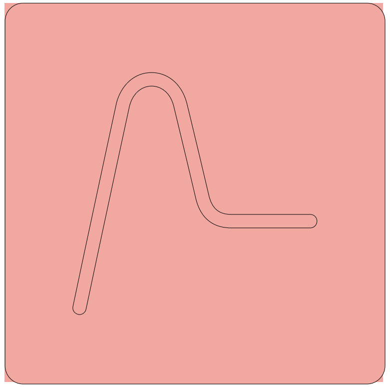
Selecting the Drive Technology



Power Source



Power Demand



Energy Management

Equipment

Environmental

- ❖ As applicable to new builds
- ❖ Ignoring existing technology know-how and legacy products

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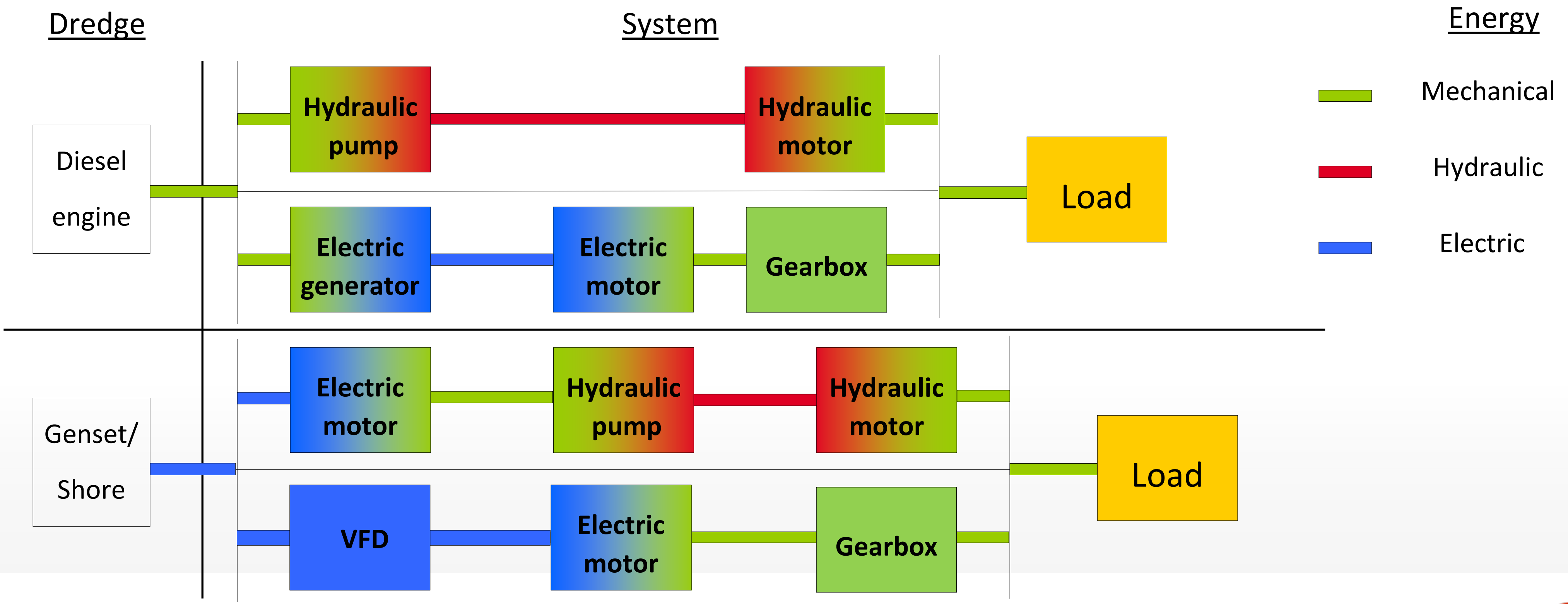
Selecting the Drive Technology

Power Source

:What type of power source available?



Selecting the Drive Technology

Power Demand

- How large are the loads on the system?

Hydraulic *systems can handle larger loads than equivalent electric systems*

- Is the power output required constant or are there peaks and troughs?

Hydraulics *are capable of handling peaks more efficiently*

- ➢ *Natural shock absorbers*
- ➢ *Accumulators currently performing better than capacitors*

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Selecting the Drive Technology

Energy Management

- Losses and efficiency

__Electric systems__ generally have less losses than hydraulic equivalents. However, __hydraulic direct drive actuators__ present less losses due to the elimination of the gearboxes

- Installed power

__Electric__ systems generally require less auxiliary power to use components. However, __hydraulic direct drive actuators__ have less starting torque and inertia

- Is the loading cyclic and can energy be recovered?

Energy recovery is much simpler and cost effective in __hydraulic systems__ i.e. accumulators.

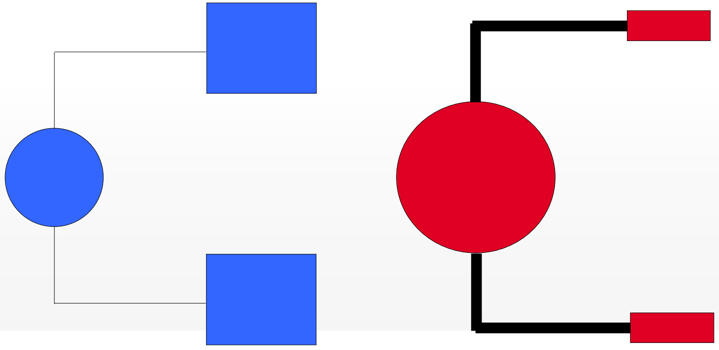
Selecting the Drive Technology

Equipment

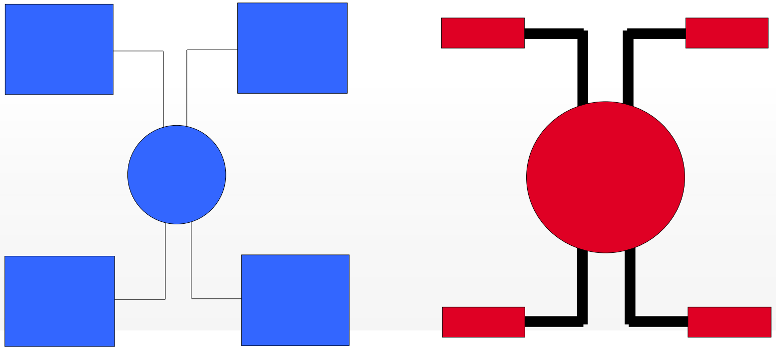
- Multiple users with a single power pack

*If there are multiple users which do not all operate simultaneously, the compactness of a **<u>hydraulic</u>** actuators will give a lighter system*

Few users → ***Electric***



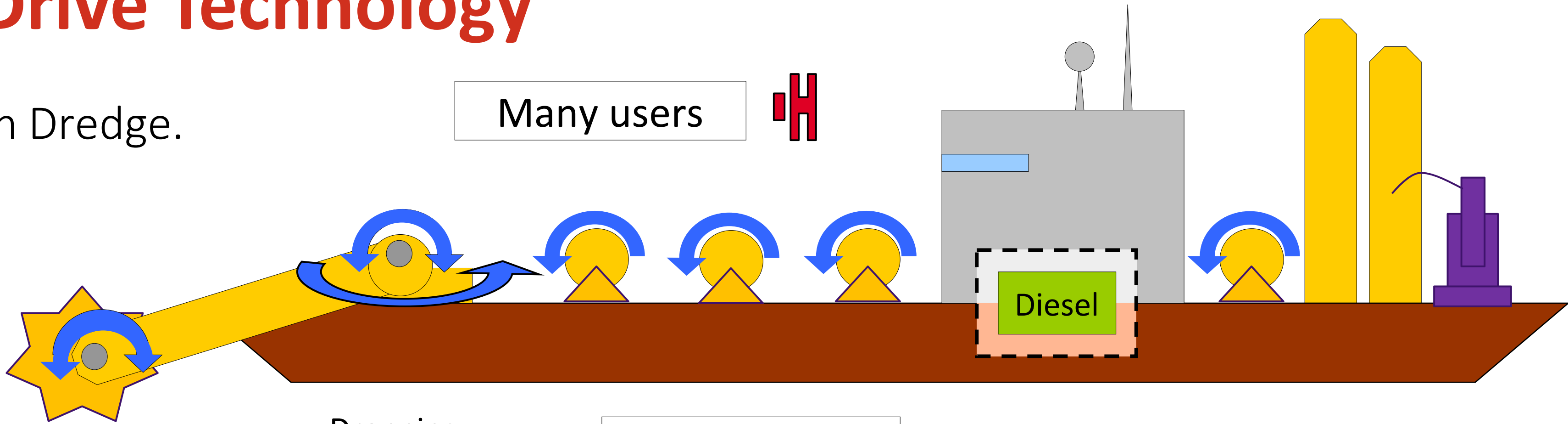
Many users → ***Hydraulic***

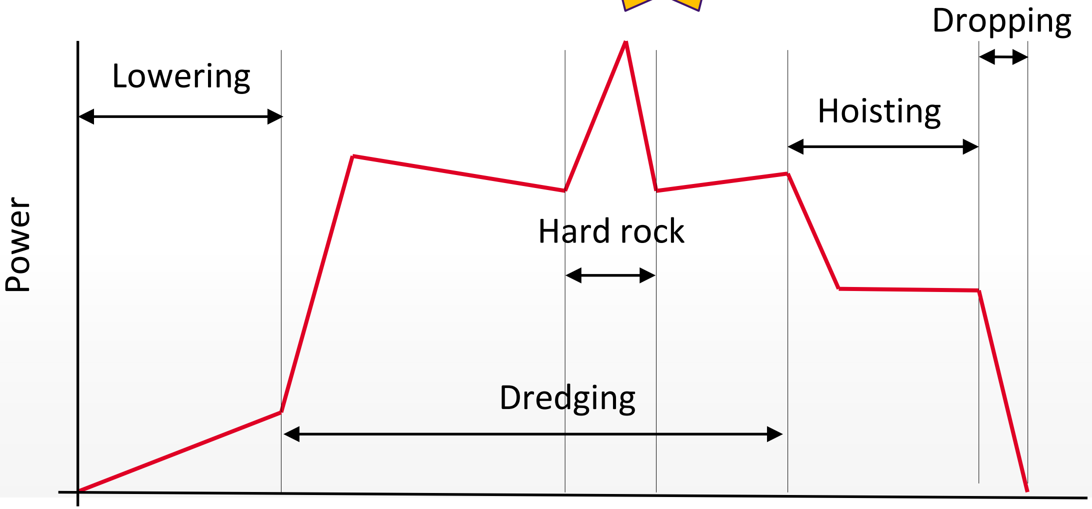


Selecting the Drive Technology

Example 1 – Cutter Suction Dredge.

Many users





Power source

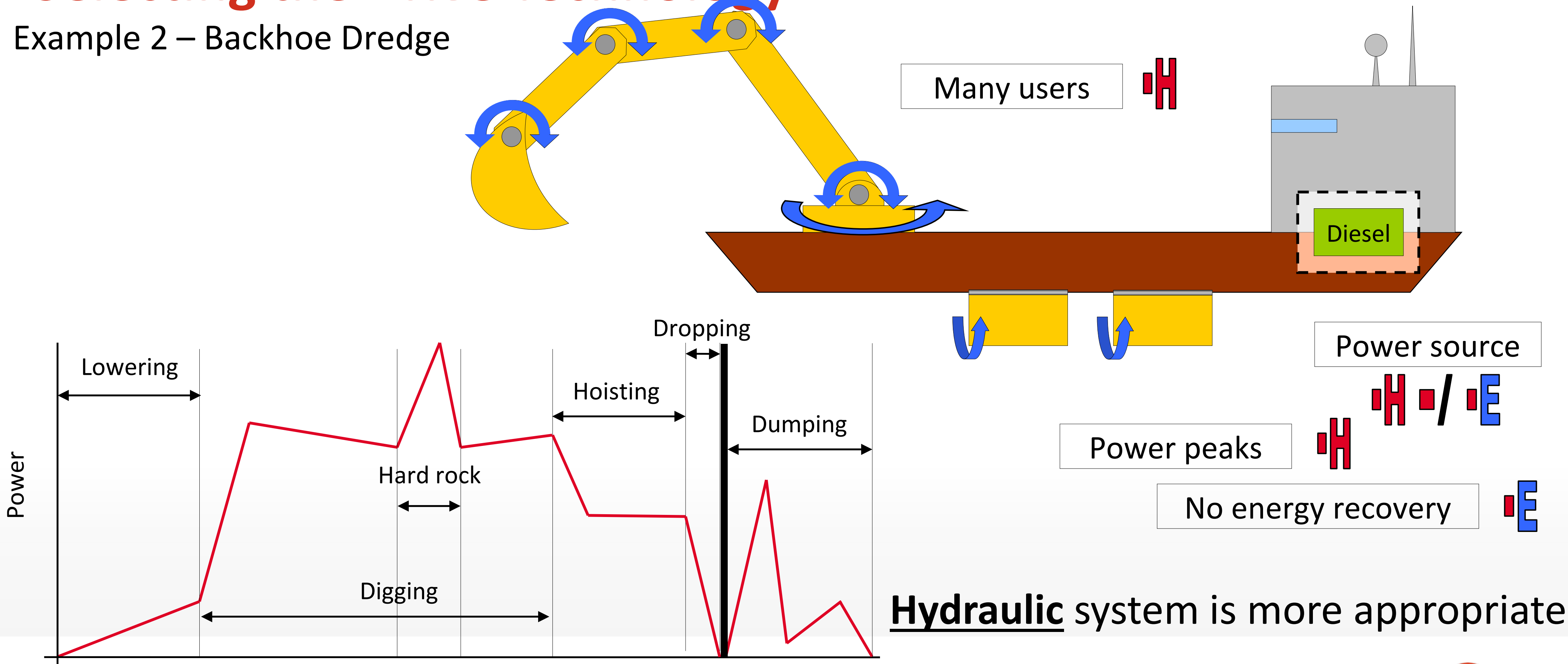
Power peaks

No energy recovery

<u>Hydraulic</u> system is more appropriate

Selecting the Drive Technology

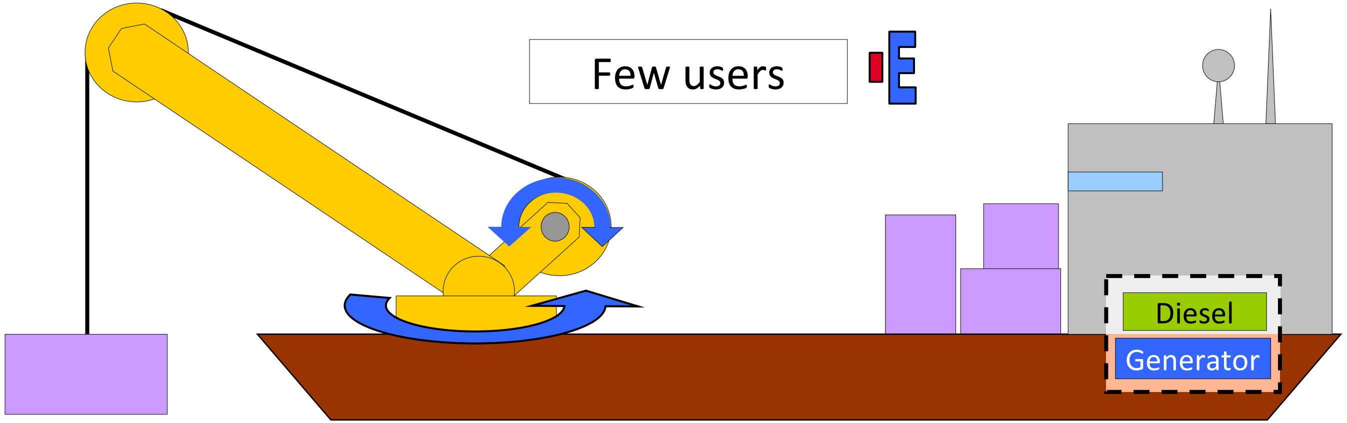
Example 2 – Backhoe Dredge



<u>Hydraulic</u> system is more appropriate

Selecting the Drive Technology

Example 3 – Transport Ship Loading

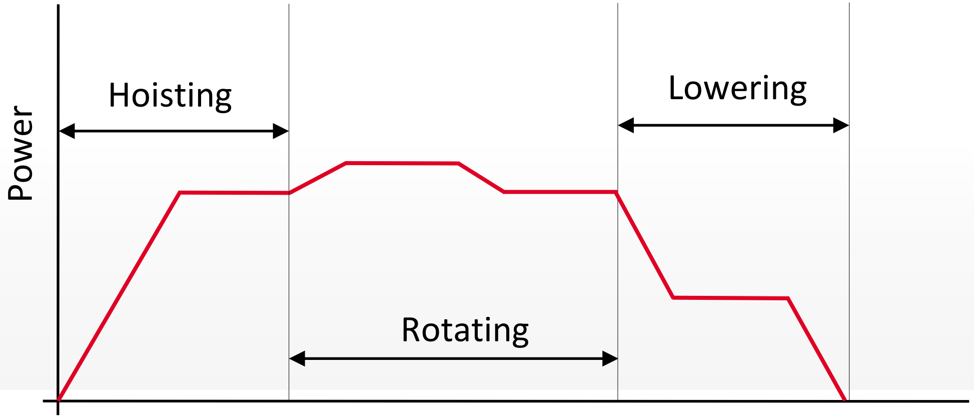


Few users

Power source

Insignificant power peaks

No energy recovery



<u>Electric</u> system is more appropriate

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Selecting the Drive Technology

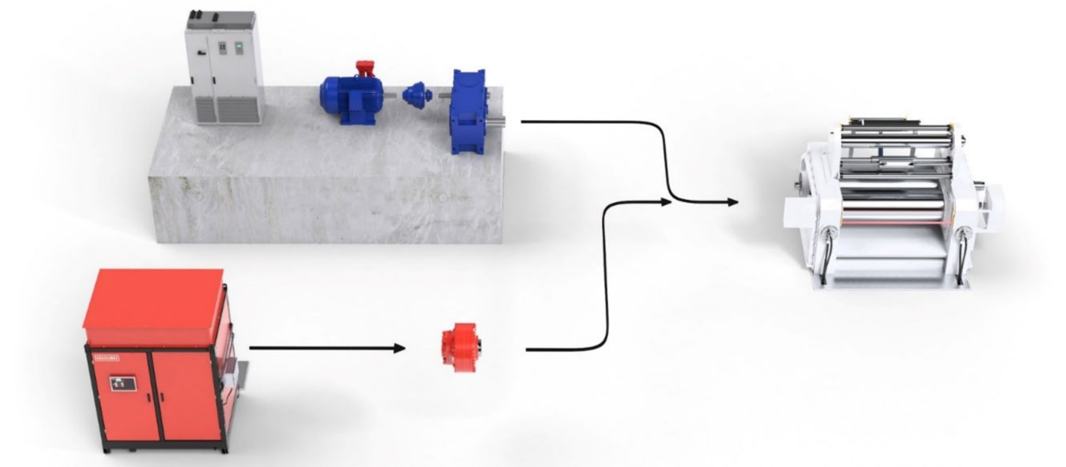
Environmental Impact

- Both hydraulics and electric actuators can use Environmental acceptable lubricants (EAL)
- Hydraulic systems utilize significantly more oil
- Environmental impact mitigation
  - Biodegradable oil
  - Design and material selection
  - Tex-sleeves

Drive Alternatives

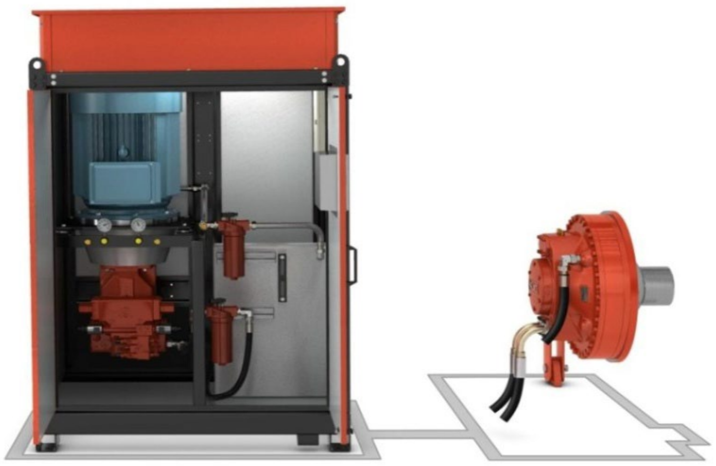
Purpose

- Compare three drive types in low speed, high torque applications:
  - Hydraulic direct drive (HDD)
  - Hydromechanical drive (HMD)
  - Electromechanical drive (ACD)



Drive Alternatives

Hydraulic direct drive (HDD)



Design

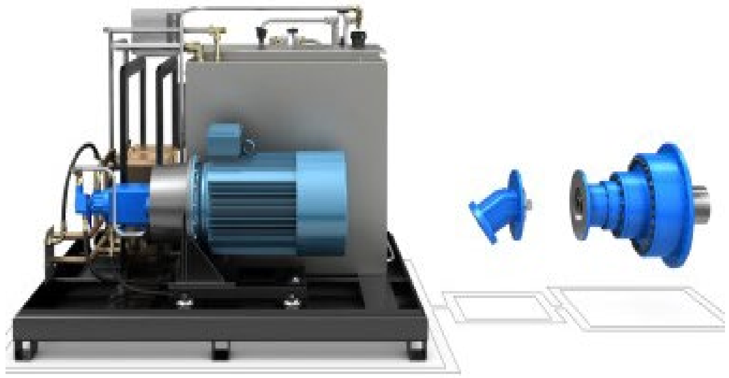
- Motor mounted directly on shaft
- Speed adjusted by increasing or decreasing oil flow
- Direction of rotation reversed by changing oil flow direction
- Motor connected to drive unit by pipes or flexible hoses

Drive Alternatives

Hydromechanical drive (HMD)

Design

- Medium- or high-speed hydraulic motor with fixed displacement
- Connected to drive shaft by means of a gearbox
- Speed adjusted by increasing or decreasing oil flow
- Direction of rotation reversed by changing oil flow direction
- Motor connected to pump by pipes or flexible hoses



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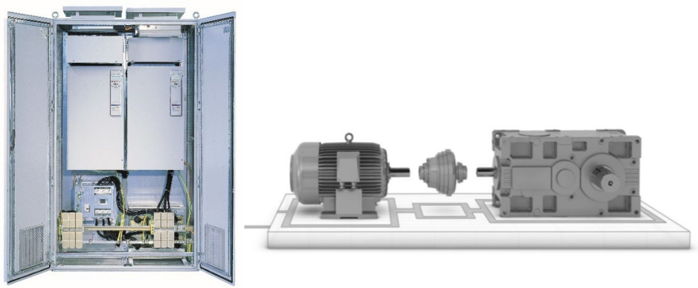
Drive Alternatives

Variable-speed electromechanical drive (ACD)

Design

- Combines a frequency converter and an AC induction motor
- Gearbox used to achieve low speed and high torque
- Fluid coupling sometimes required for shock load protection
- Electric motor speed controlled by converter
- Shielded cables between converter and motor

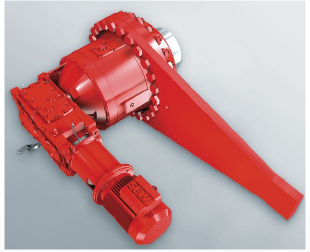


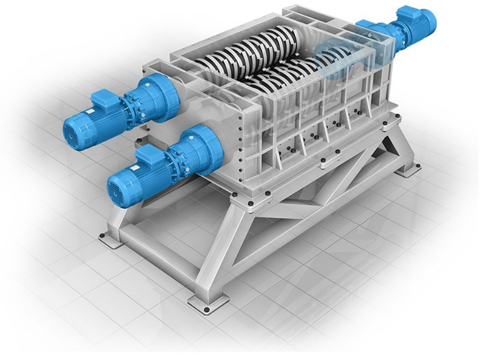
Drive Alternatives

Physical considerations

ACD:

- Size at shaft (large size and weight), mostly requiring foundation
- Gearbox maintenance & change problematic
- Harsh environments, extreme temperatures or high power -> enclosures and shielding
- Additional cooling & lubrication





HDD:

- Size at shaft (small size and weight)
- Power & torque density is high in relation to weight
- Direct mounted on shaft (coupling or splines)
- Separate drive unit
- Closed loop system – insensitive to harsh environments

HMD

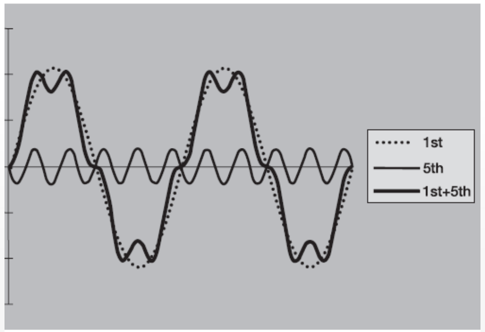
- Size on shaft
  - Gearbox added weight on shaft
  - Long drive assembly
- Extra cooling & lubrication of gearbox

Drive Alternatives

Harmonic distortions

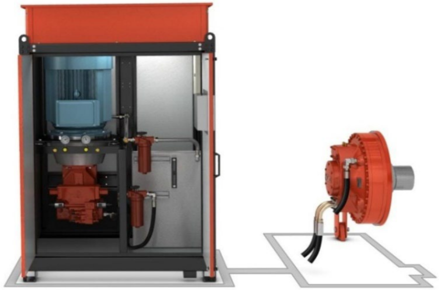
ACD

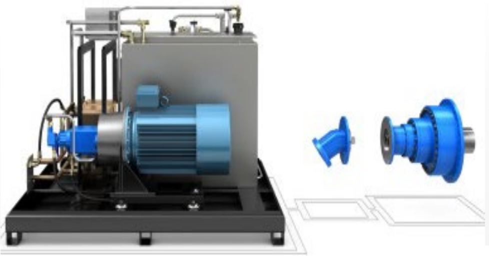
- Harmonic distortions on the grid can damage connected equipment
  - How it arises:
    - ACD speed is adjusted by changing the net frequency
    - To do so, the net frequency is divided into several sine waves
    - Sine waves are combined to create the required frequency
    - The result is not a clear sine wave, leading to harmonic distortion
  - Harmonics can be reduced with low-harmonic converters or external filtering
    - Adds to the drive cost
    - Slightly increases power losses



HDD, HMD

- Electric motor always runs at rated speed
- No harmonic distortion produced
- No additional equipment needed



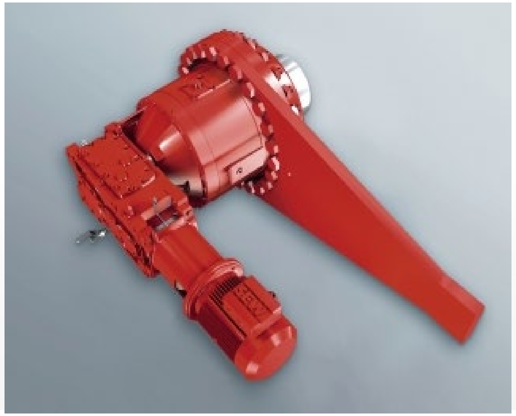


Drive Alternatives

Over-dimensioning

When using an ACD

- Converter and motor over-dimensioned to handle high starting torque, frequent starts and stops, etc.
- Gearbox over-dimensioned to handle application requirements (such as shock loads) and ensure service life
- Built-in losses due to over-dimensioning reduce drive efficiency

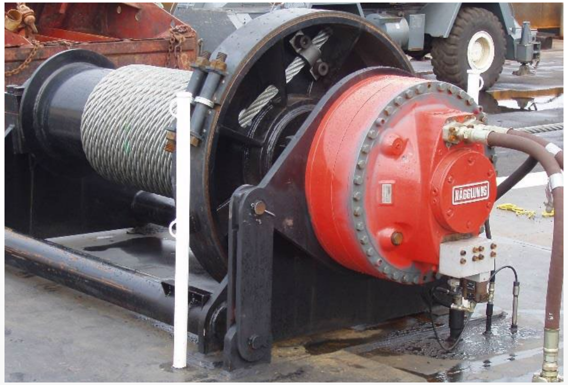


When using an HMD

- Gearbox oversized in the same way as ACD
- Built-in losses due to over-dimensioning reduce drive efficiency

When using an HDD

- No over-dimensioning required



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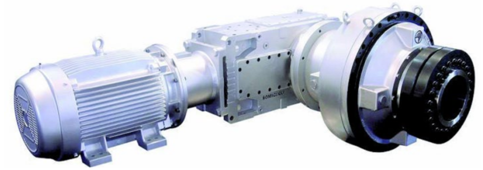
Drive Alternatives

Moment of inertia - comparison

- High-speed drive components have a low moment of inertia
- Moment of inertia for high-speed components must be recalculated to the gearbox output shaft
- Components connected to the high-speed shaft contribute most
- Moment of inertia is negligible for the gearbox

$$J_{Total} = J_1 * i^2$$

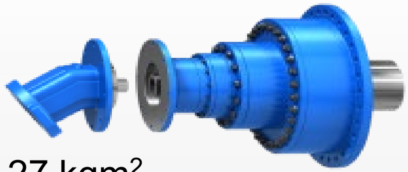


$J_{tot} = 15{,}666\ kgm^2$

$J_1 = 2.9\ kgm^2$ $i = 73.5 : 1$

$i = 1 : 1$

$J_1 = J_{tot} = \sim 20 kgm^2$



$J_{tot} = 1{,}459\ kgm^2$

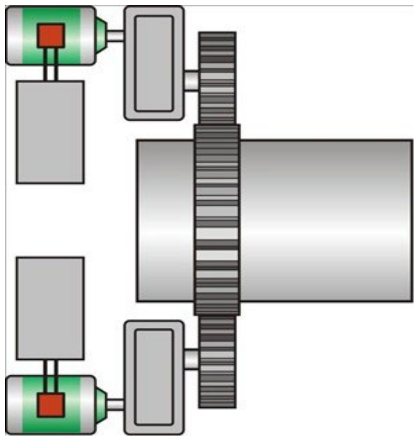
$J_1 = 0.27\ kgm^2$

Drive Alternatives

Load sharing

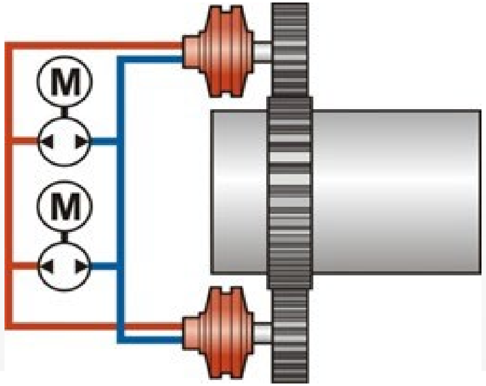
When using an ACD

- Complexities with sharing the load equally
- Risk of vibrations and gearbox fatigue
- Problems may be reduced i.e., if one motor is used for position control and the other for torque control



When using an HDD or HMD

- Hydraulic motors connected to a common hydraulic system
- 100% load sharing automatically
- No vibration risk



Drive Alternatives

Quick comparison table

Characteristics	HDD	HMD	ACD
Starting torque	200–300%	200–300%	200%, time restricted
Standstill time at load	Unlimited	Unlimited	Limited due to overheating
Torque throughout speed range	Full torque	Full torque	Reduced continuous torque at lower speeds
Sensivity to shock loads	Not sensitive	Sensitive	Very sensitive – fluid coupling or overdimensioning required
Rapid stops	Very fast	Fast	Slow
Start/stop frequency	Unlimited	May be limited by gearbox	Limited
Moment of inertia	1	20–100	100–1000
EAL /Biodegradable compatibility	Yes	Yes	Yes

Drive Alternatives

Characteristics	HDD	HMD	ACD
Gearbox required	No	Yes, in most cases	Yes
Foundation required	No	No	Yes, unless mounted with a torque arm
Weight of units connected to driven shaft	Low	Higher, depends on gearbox size	Higher, depends on drive size
Size at driven shaft	Very compact	Longer axis than direct drive	Bulky, especially at high power
Load sharing	100%	100%	Difficult, load on electric motors must be compared
Redundancy with multiple drives	High	Limited - dependent on remaining gearbox capacity	Very limited, drive dependent on power to develop torque
Sensitivity to harsh environments	Not sensitive	Gearbox may need cooling and flushing	Converter must often be insulated or installed in an air-conditioned room
Harmonic distortion	No	No	Yes, low-harmonic converter or filter required