What's New In Medium Voltage Drives

William Lockley
Technical Consultant
Lockley Engineering

Richard Paes
Global Industry Technical Consultant – Oil & Gas
Rockwell Automation

IEEE Northern Canada & Southern Alberta Sections
PES/IAS Joint Chapter Technical Seminar

Outline

- Adjustable Speed Drive Basics
  - What is a “Drive”
  - Purpose and benefits of ASD
  - Typical Applications
- Adjustable Speed Drive Designs
  - ASD Design Fundamentals – Semiconductors
  - Voltage / Current source
  - Rectifiers
    - Passive / Active Front End
    - Multi-pulse
  - Inverters
    - 2 Level
    - Multilevel
    - Series H bridge

Outline

- Adjustable Speed Drive Basics (continued)
  - Typical voltage source topologies
  - Typical current source topologies

- What’s New with MV Drives
  - New directions and focus
  - Industry Trends
  - Specialized Applications
  - New Frontiers

Outline

- IEEE 1566 Large Drive Standard
  - Adjustable Speed Drive System (ASDS)
  - Adjustable Speed Drive History
  - Purpose and need for the standard
  - Status of the standard
  - IEEE 1566 2nd Edition
  - Technical changes and innovations
  - Overview
  - Unique applications such as marine, long cable runs and generator supply
  - Data Sheet and Data Sheet Guide
  - How to apply and order a MV ASD
- Conclusion

What is a “Drive”?

A “Drive” is the truncated form of:

- Adjustable Speed Drive (ASD) *or*
- Variable Frequency Drive (VFD)

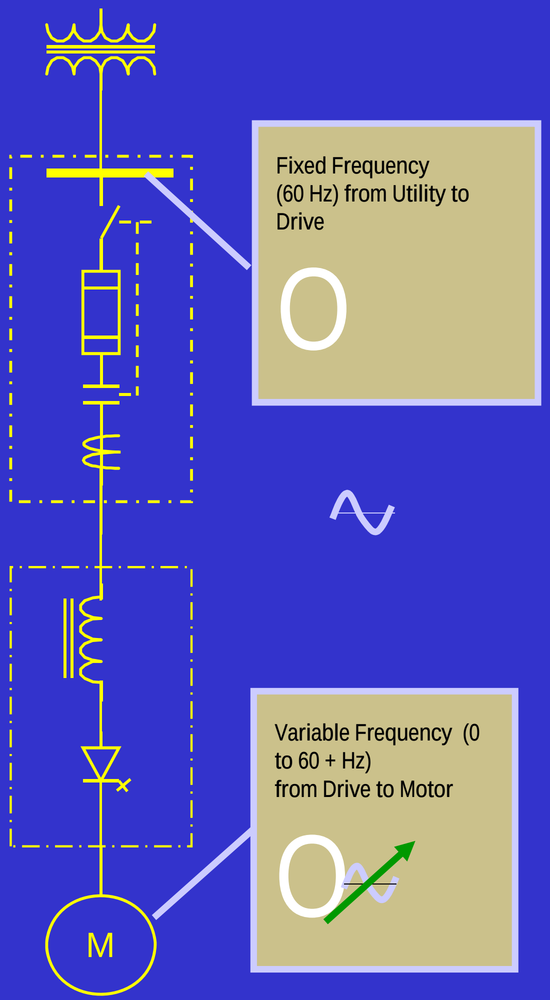
As the complete description better conveys, it is an AC controller which allows us to adjust the speed of an electric motor (by changing the frequency of the power delivered to the motor.

MOTOR SPEED = $\frac{120 \times F}{P}$

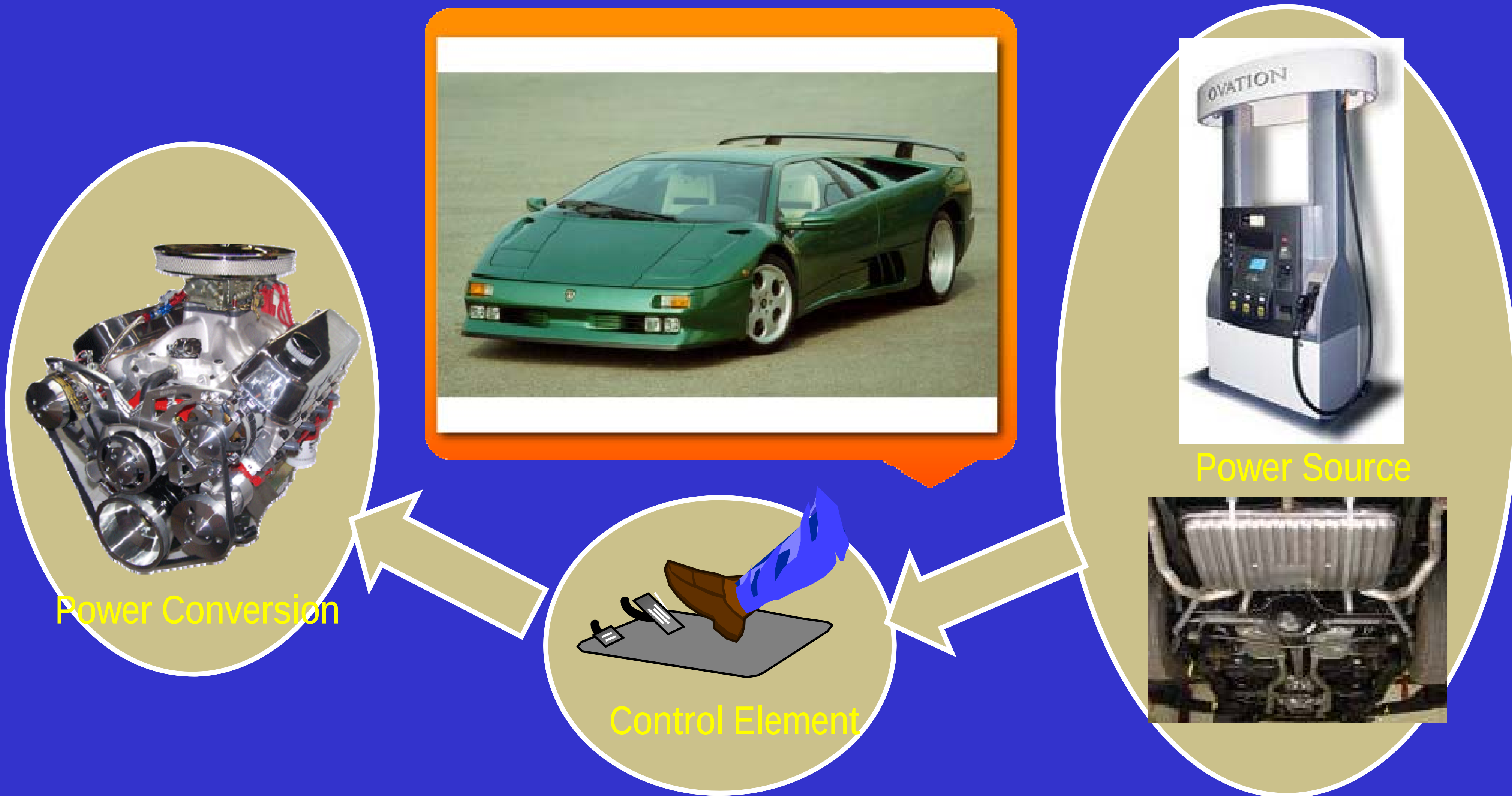
120 = constant
F = supply frequency (in cycles/sec)
P = number of motor winding poles

Both the “120” and “P” portions of the formula are fixed, the only item we can use to adjust the motor speed is “frequency”

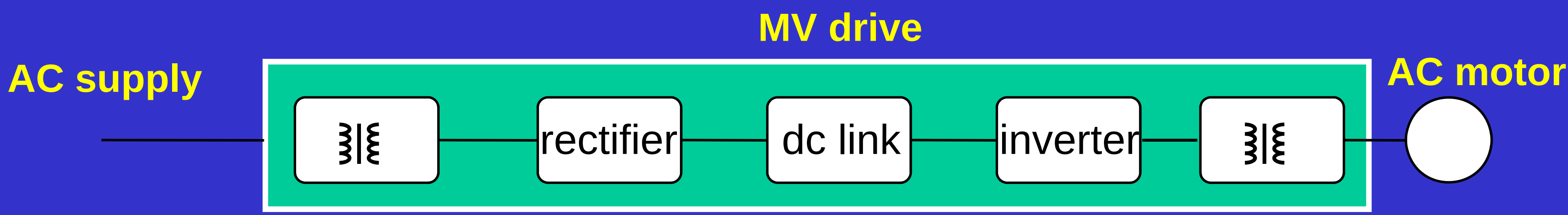
Adjustable Speed AC Drive



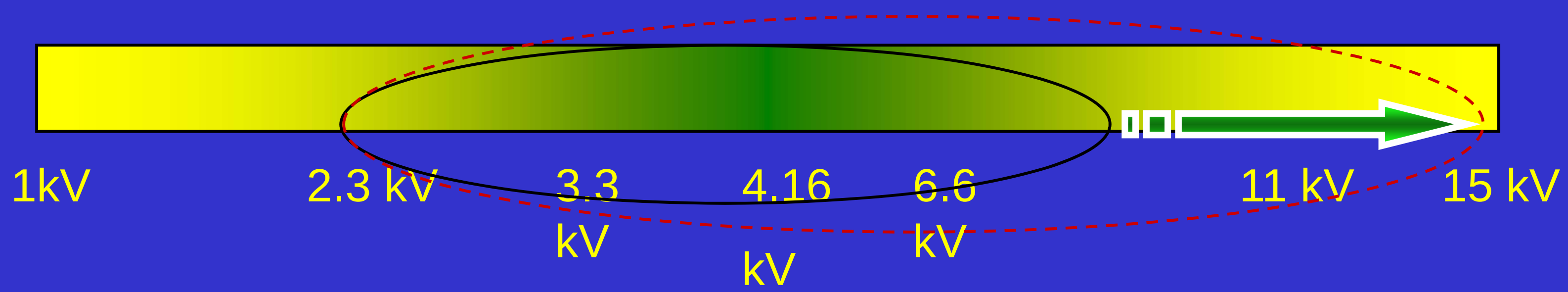
What is a "Drive"?



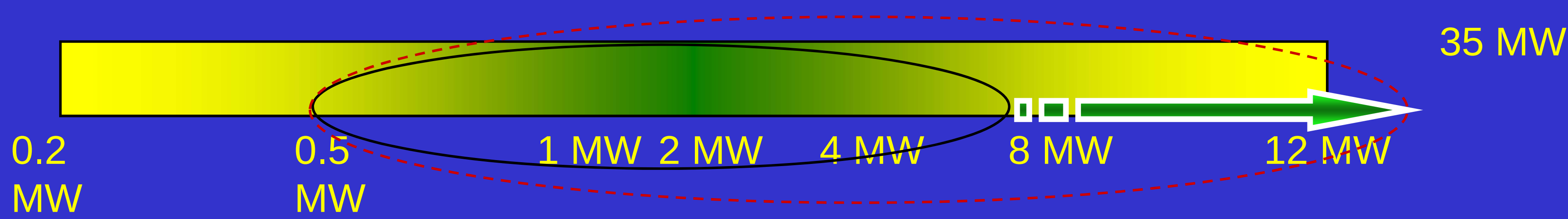
Medium Voltage Drive



Voltage Range



Power Range



Why Use Adjustable Speed Drives ?

BASICS

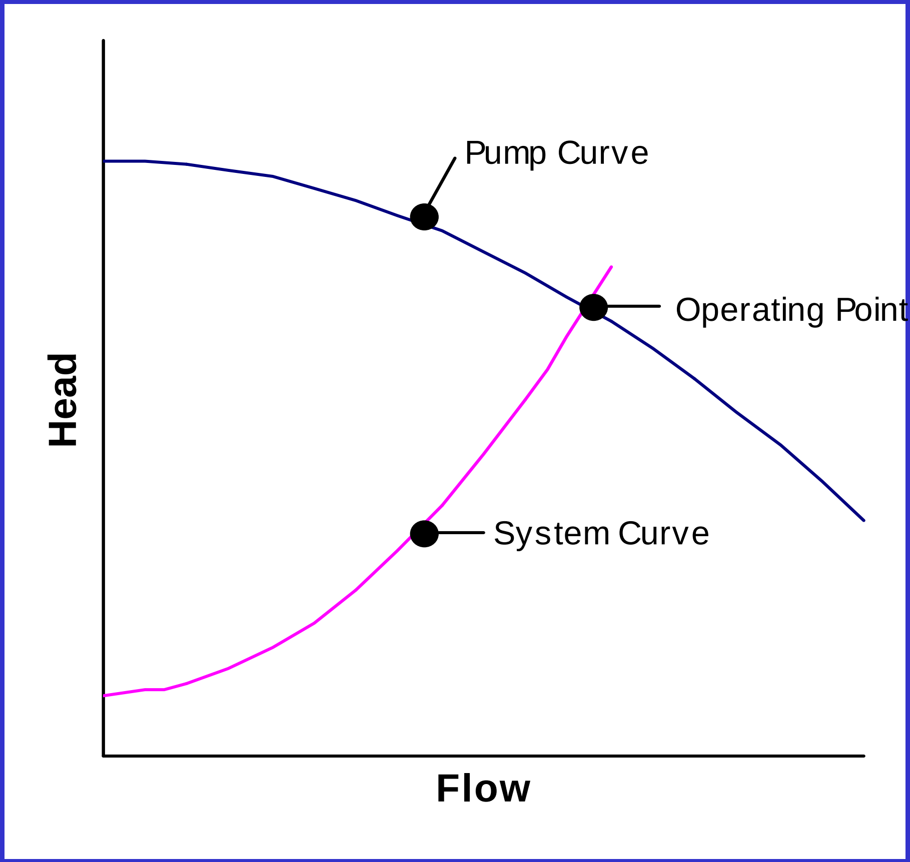
- Match the speed of the drive / motor to the process requirements
- Match the torque of the drive / torque to the process requirements
- Energy Savings

Why Use Adjustable Speed Drives ?

- Reduce maximum utility demand – electrical and cost
- Meet utility flicker restrictions while starting large loads
- Improve equipment life due to soft starting
- Increase mechanical equipment life by running at slower speeds
- Controlled application of torque
  - i.e. reduced water hammer effects
  - i.e. conveyors
- Reduced Pump Cavitation Problems
- Reduce preventative and corrective maintenance costs by eliminating complex mechanical equipment – valves, dampers, etc.
- Allows the use of standard induction motors while increasing performance in terms of torque, inrush and power factor
- Reduce motor stress - transient torques, thermal heating at start condition, no limit of starts/hr, high inertia loads
- Improve process control by ‘infinite’ speed control and better information / tie in with supervisory control system
- Forward / Reverse operation
- Regenerative braking

ASD on Pump Example

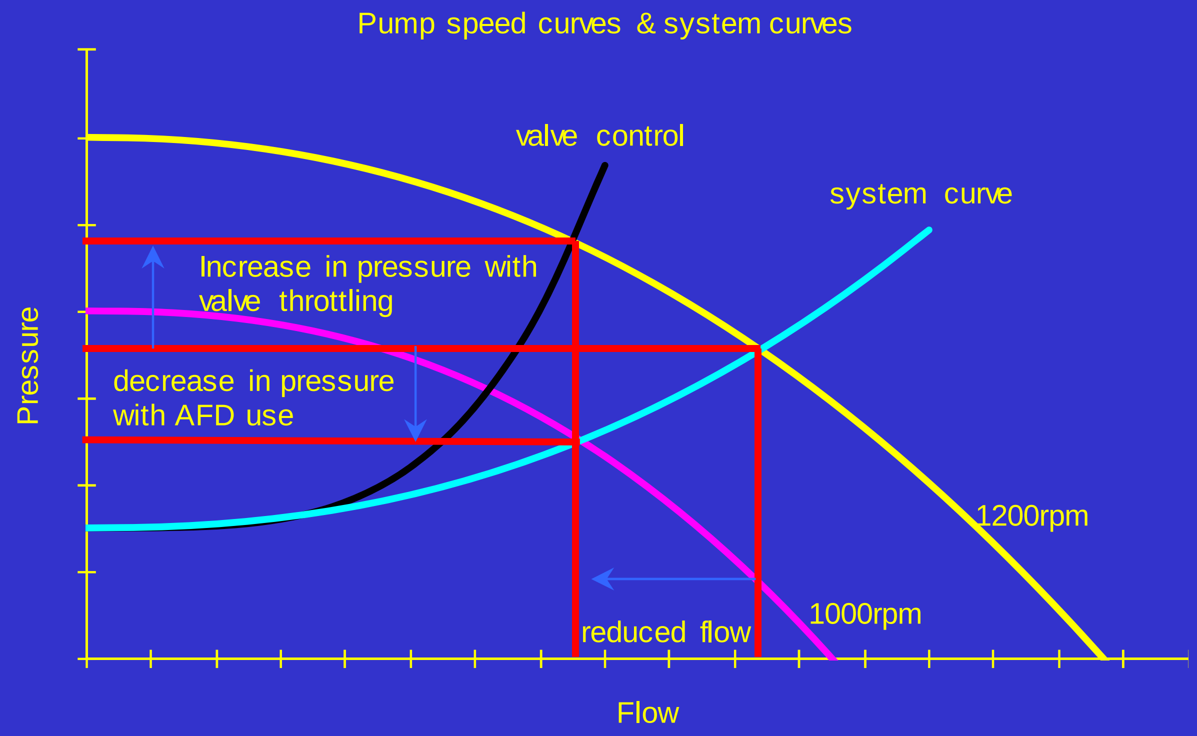
- All pumps must be sized to meet maximum flow and the static & dynamic heads of the system – “System Curve”
- Pump is selected such that the “Pump Curve” intersection with the System Curve gives the desired “Operating Point”



Pump Operating characteristics

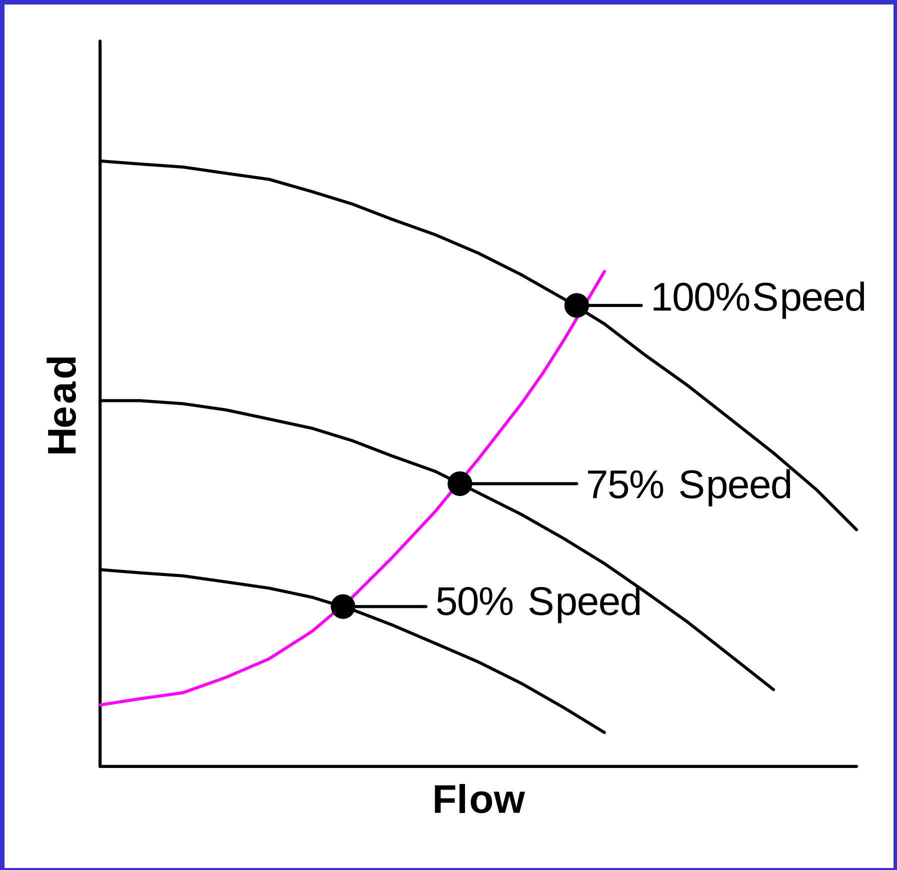
- Without the use of an ASD, the flow must be controlled with the use of a valve which drops pressure across it

- Pressure drop = Loss

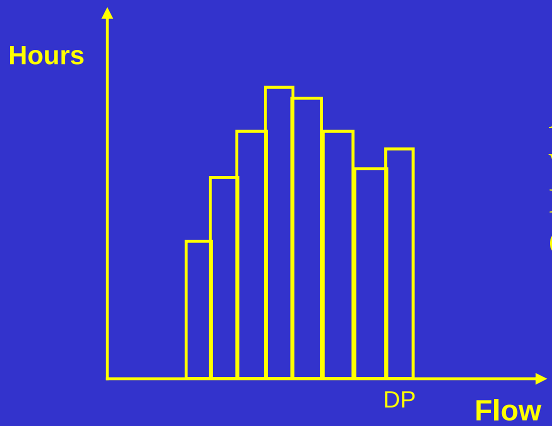


ASD on Pump Example

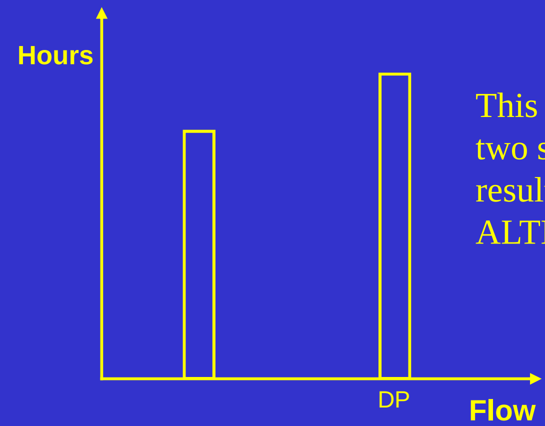
Adjustable speed operation allows flow to be controlled by shifting the operating point without energy losses associated with restricting flow external to the pump



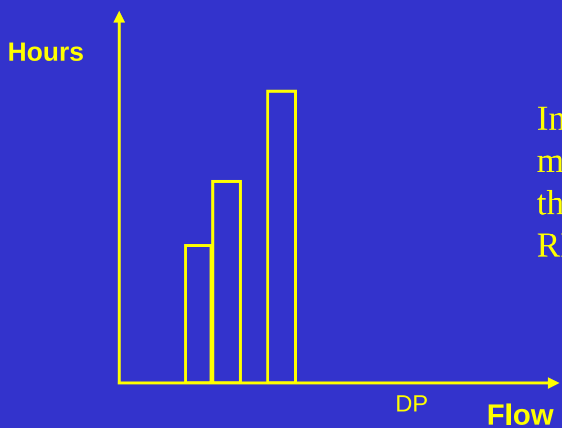
Energy Savings Considerations



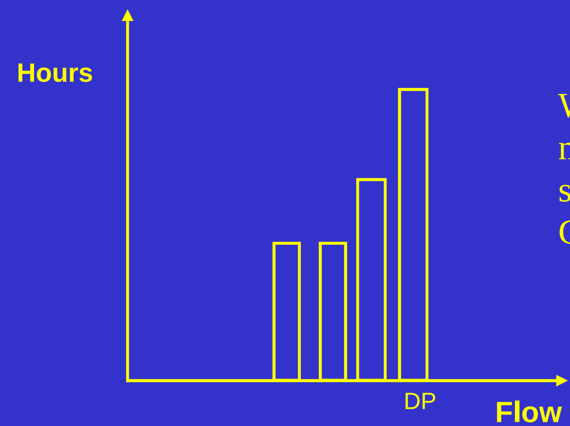
A high Degree of Variability will typically result in significant Energy Savings
GOOD CANDIDATE



This is a case where the use of a two speed control device might result in a better economic solution
ALTERNATIVE SOLUTION



In this type of situation it might make engineering sense to rerate the pump
REDESIGN SYSTEM



When the system is operated near the Design point, less savings are obtained
GOOD CANDIDATE

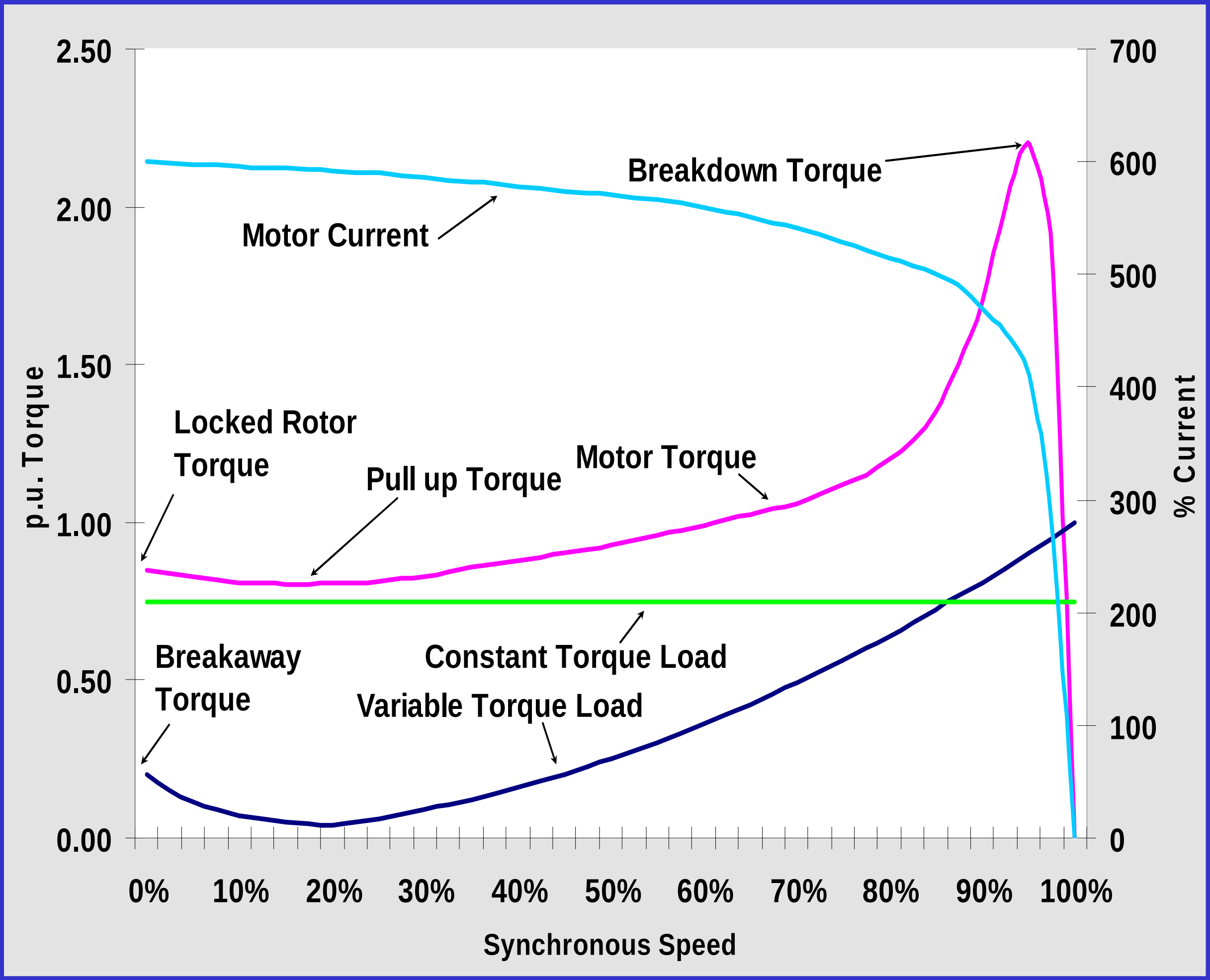
Improve AC Induction Motor Performance

Typical Induction Motor Performance

- API inrush limit – 650%
- 60 to 80% locked rotor torque at start typical
- Limited number of starts
  - Nema defines (2) cold, (1) hot
  - API 541 defines (3) cold, (2) hot

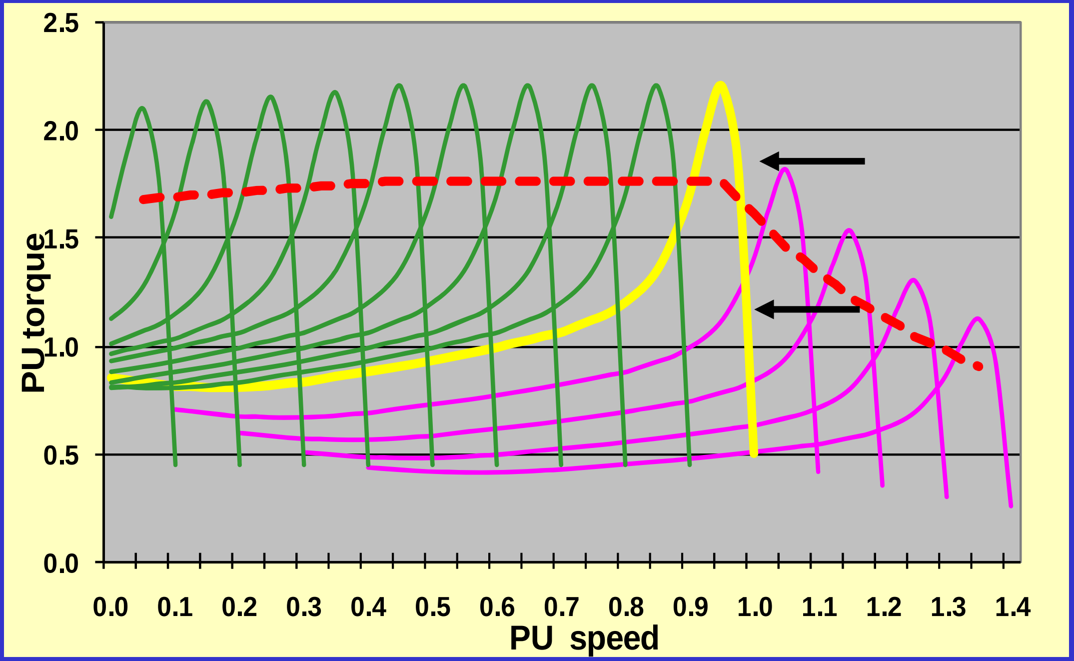
Operation on ASD

- Inrush current limited to starting torque required
- Torque at start improved
- Number of starts improved



AC Induction Motor Operation with Adjustable Speed Drive

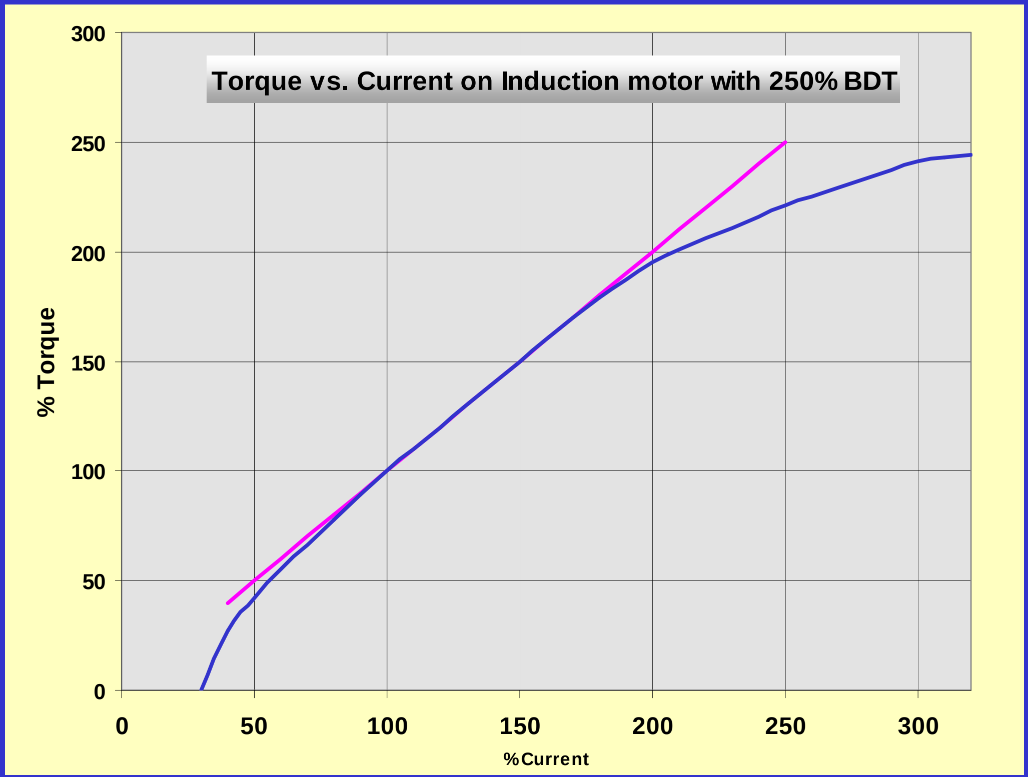
- Allows continuous operation at reduced speeds by altering output frequency to motor
- Improves motor operating characteristics beyond across the line starting – torque / current
- Motor operates on right side of breakdown on torque curve
- Starts are not limited as on across the line start
- Torque can be applied smoothly to lessen impact on mechanical drive train



High Torque Operation

Operation of Induction Motor on ASD

- Near rated break down torque can be realized during acceleration
- Starting current is proportional to the torque in ranges of 50 to 200%
- Drive must be sized accordingly to allow for this amount of current for the required duration of the start
- AFE PWM topologies allow pulse dropping to extend the drive rating at start, during short term overload and as an operating contingency



Published Ratings – Duty Profiles

- Continuous Operation
- Service Factor
- Normal Duty – 110% for 60 seconds (115% for 60 seconds)
- Heavy Duty – 150% for 60 seconds
- Variable Torque Load Profile
- Constant Torque Load Profile
- Intermediate Duty – 110% for 60 seconds
- Constant torque Load Profile

Load Requirements

Load Profile is the prime consideration when sizing an ASD

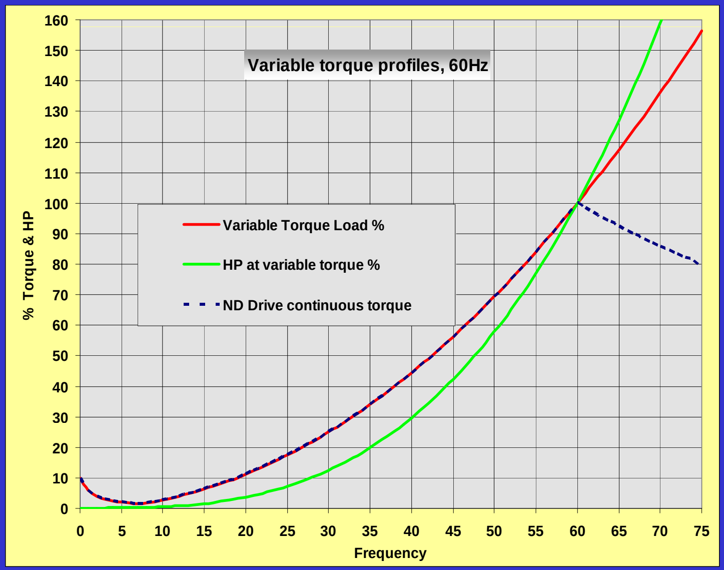
- Continuous operation
- Starting

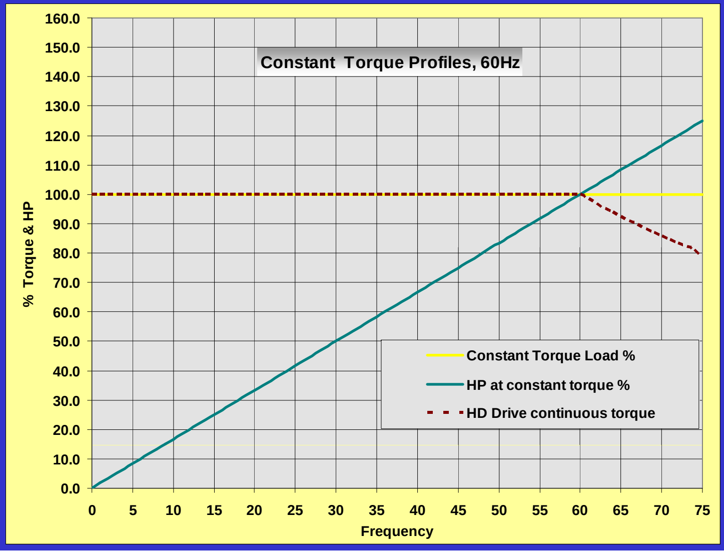
Motoring

- Motor Rating – FLC particularly
- Starting Overload
- Continuous Operation
  - Ambient / Environmental Conditions
  - Load type – variable / constant torque
  - Service Factor
- Cyclic Loading / Overloading

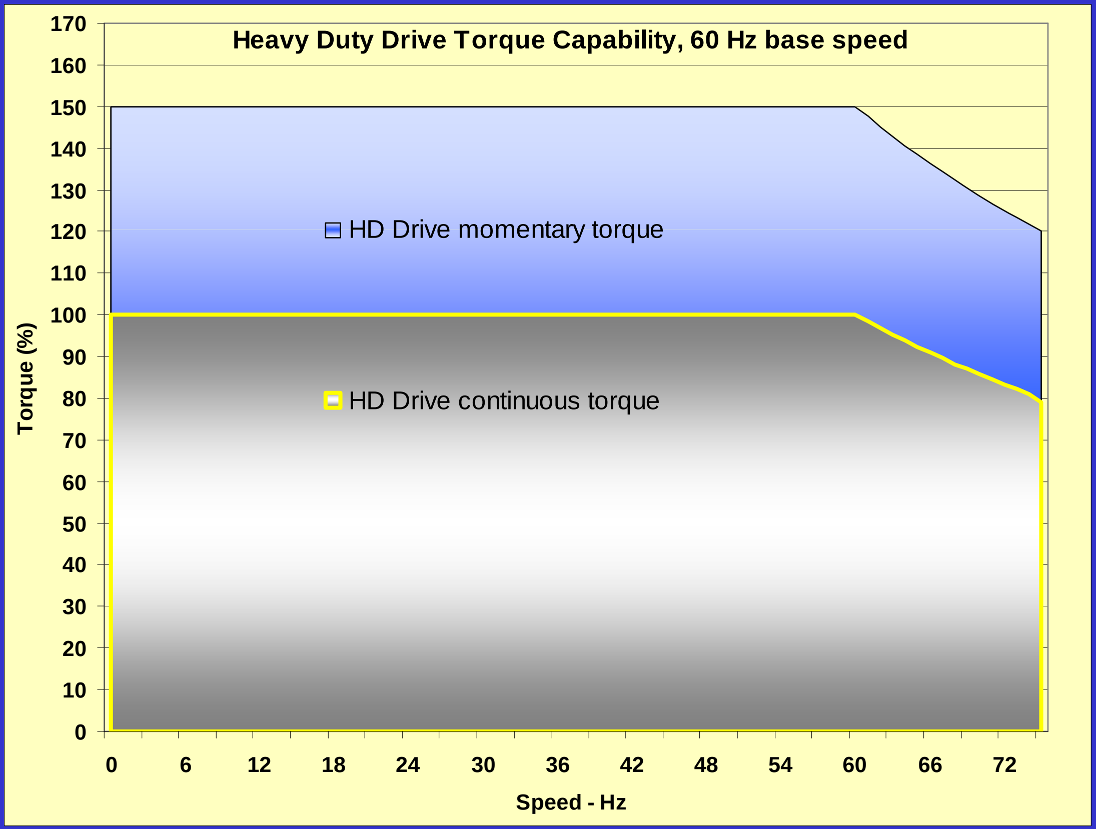
Braking

- Overhauling load
- Similar aspects to the above

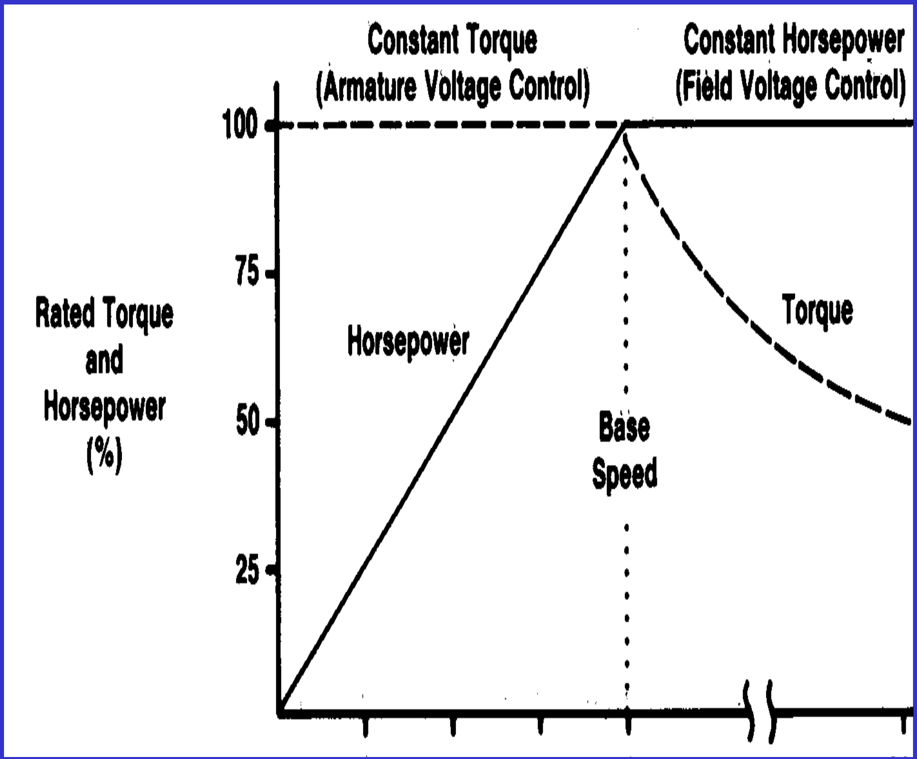




Heavy Duty Loading



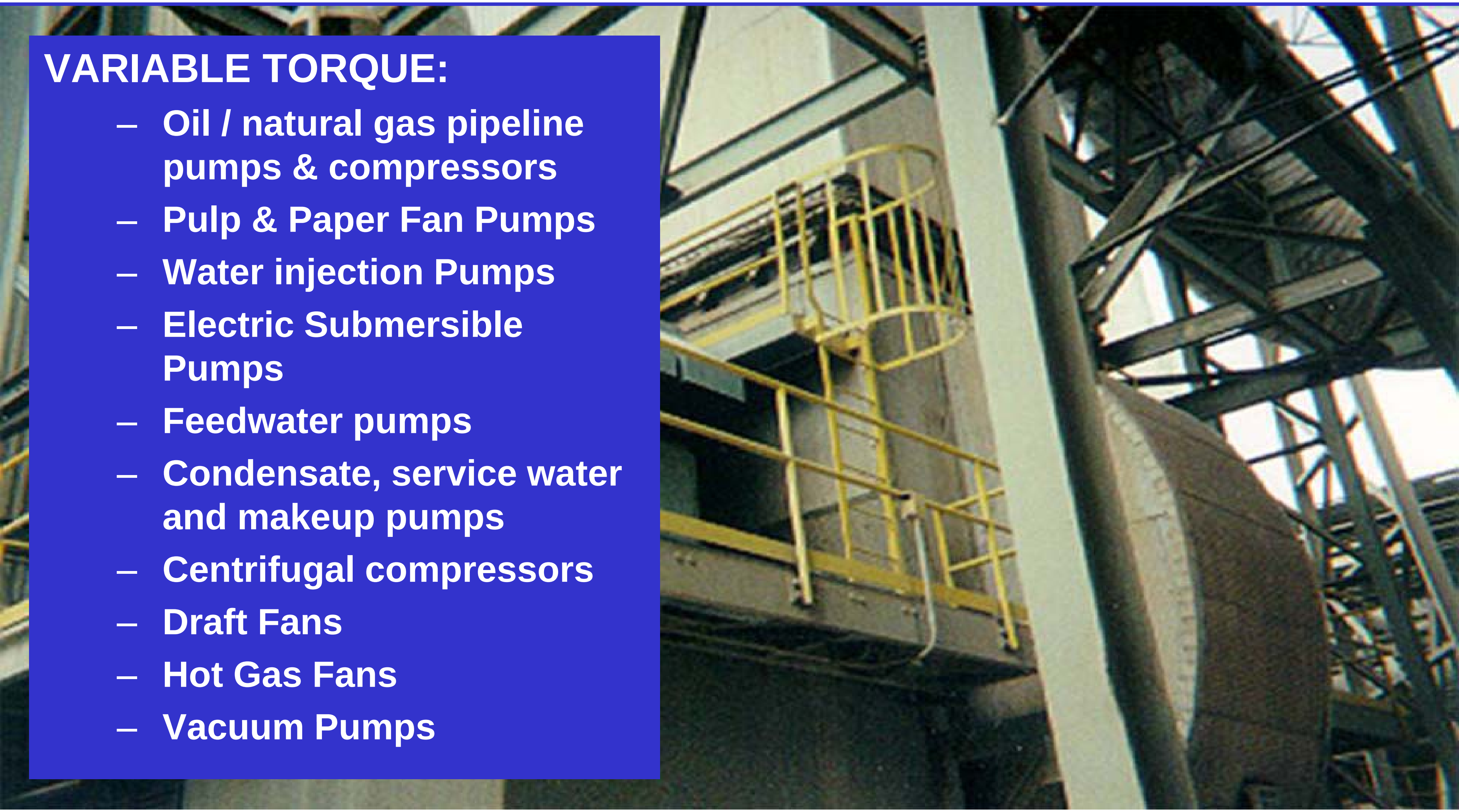
Operation Above Base Speed



$$HP = \frac{Torque \cdot Speed}{5250}$$

- Further benefit of ASD is the ability to run above base speed
- Note that torque is not unlimited and must be considered in sizing when operating above rated speed

Variable Torque Applications

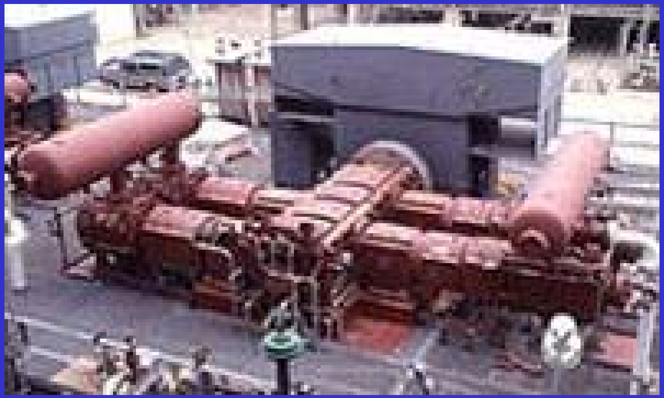


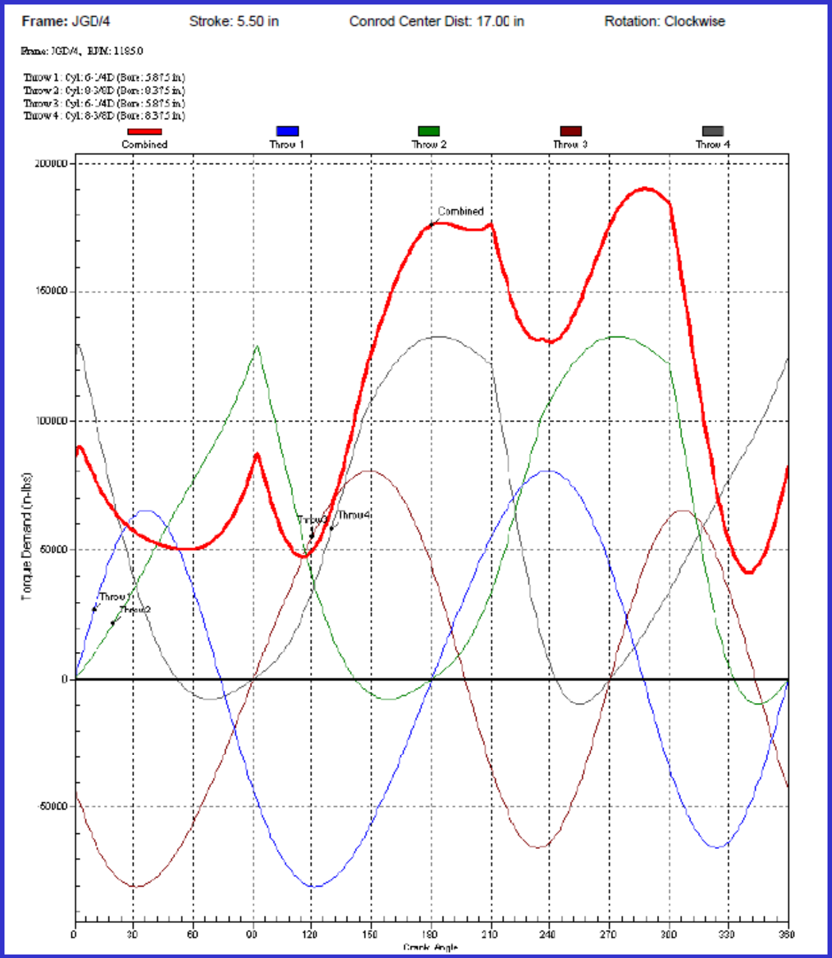
VARIABLE TORQUE:

- Oil / natural gas pipeline pumps & compressors
- Pulp & Paper Fan Pumps
- Water injection Pumps
- Electric Submersible Pumps
- Feedwater pumps
- Condensate, service water and makeup pumps
- Centrifugal compressors
- Draft Fans
- Hot Gas Fans
- Vacuum Pumps

Reciprocating Compressors

- Typically < 100% torque to start
- Constant torque load profile
- 50 to 100% speed range
- High pulsating torque
- Potential for unstable drive operation due to torque cycle
  - tuning of drive speed and current controllers
- Higher risk of vibration with rich load torque harmonic content
  - torsional analysis can provide information for inertial or damping requirements

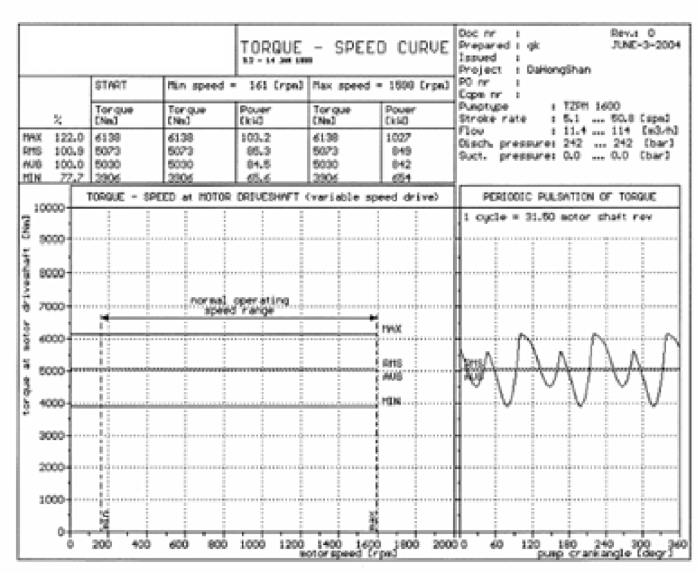


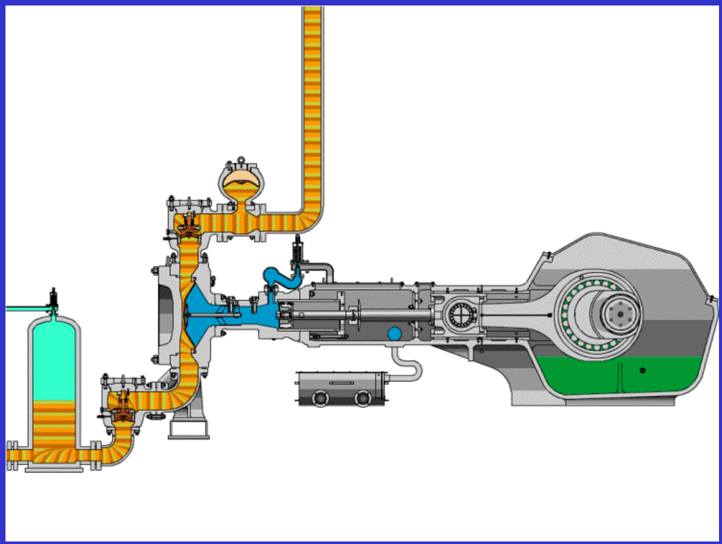


Crank Effort Torque Curve

Positive Displacement Pumps

- Crank angle shows Pulsation of load torque over 1 rev of pump shaft revolution
- Peak at 100 degrees = 6138 Nm
- Min at Separation of 120 degrees = 3906 Nm
- Torque r.m.s. = 5073 Nm
- Torsional vibration study may help in determining coupling, flywheel and torsional damping requirements





Apron Feeder / Conveyor Applications

Constant torque application

Rated torque is required over 0 -100% speed

Short term 150% start torque is typical but torque levels and duration requirements vary with each application

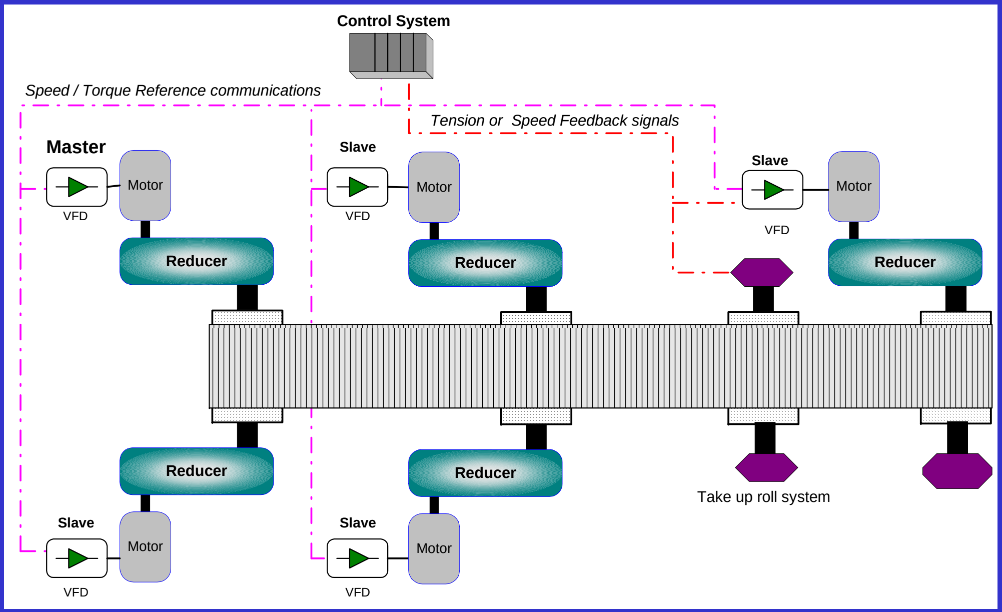
Higher / custom starting torques can be accommodated

Different dynamics and control requirements are encountered depending on conveyor configuration

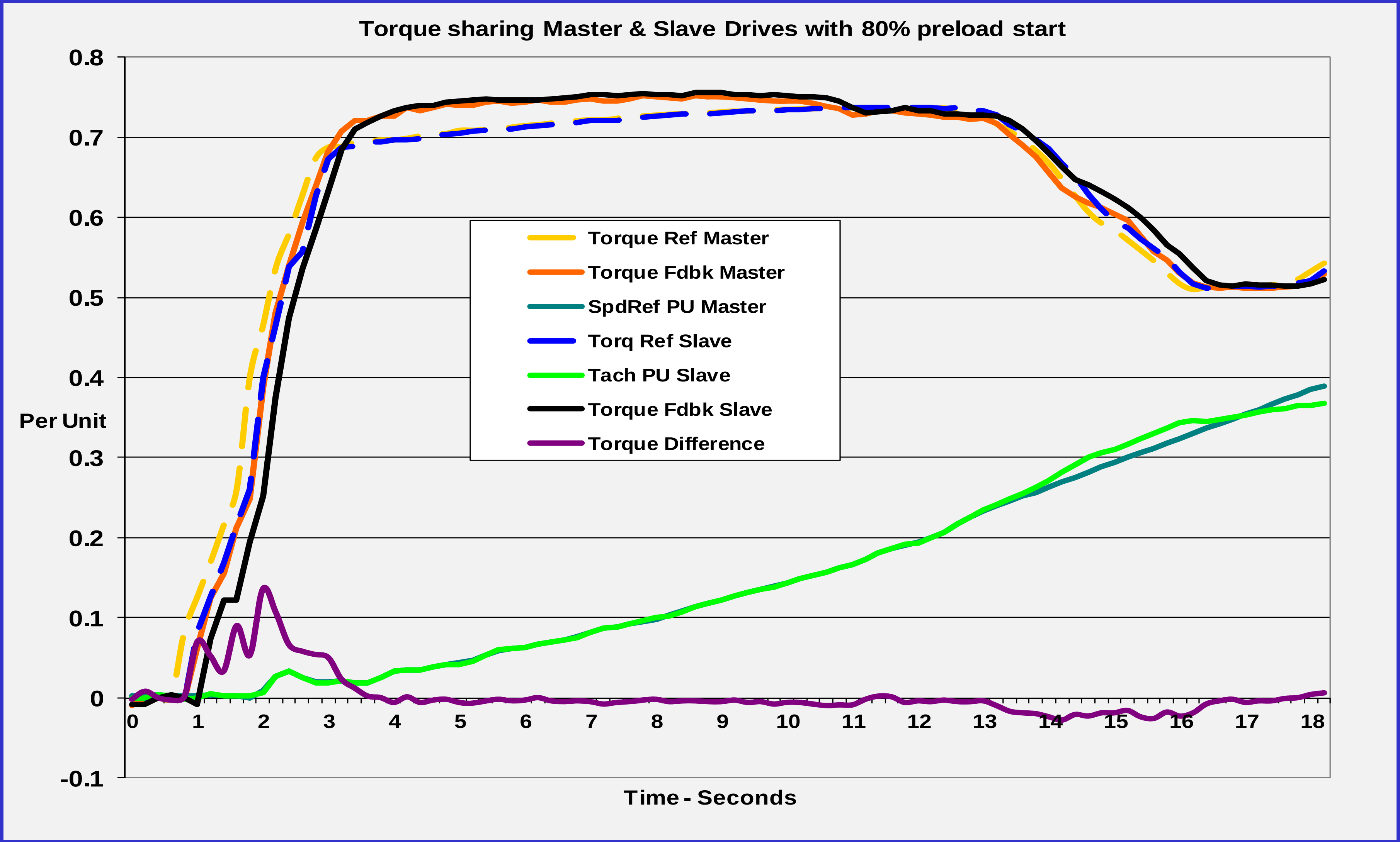
- Uphill, downhill, level or combination of these
- Different lengths, tension control systems
- Single or multi-motor
- Drive pulley arrangement

Affected parameters

- Starting torque
- Regenerative Braking
- Load-sharing
- Brake interface



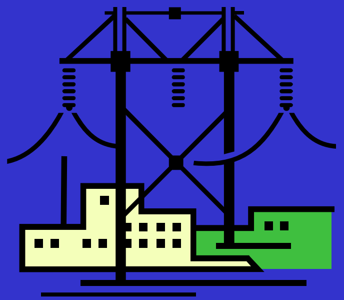
Load Sharing



Slurry Pumps

Adjusting the speed of the pump:

- Optimize slurry Flow to meet requirements without valves.
  - Saves energy
  - Reduces wear – reduction to 50% speed increases impeller life by 6 times
- Maintain the flow as pump wear occurs.

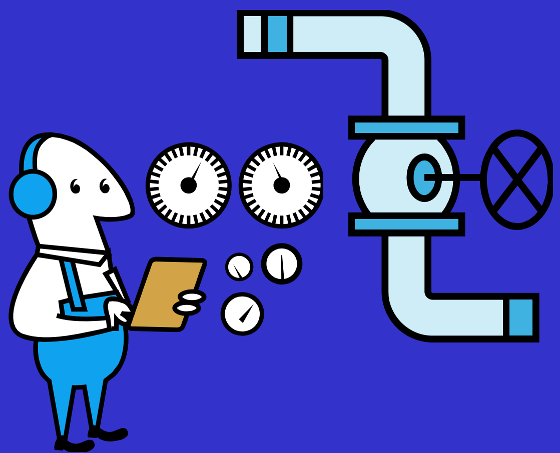


Starting the pumps with ASDs

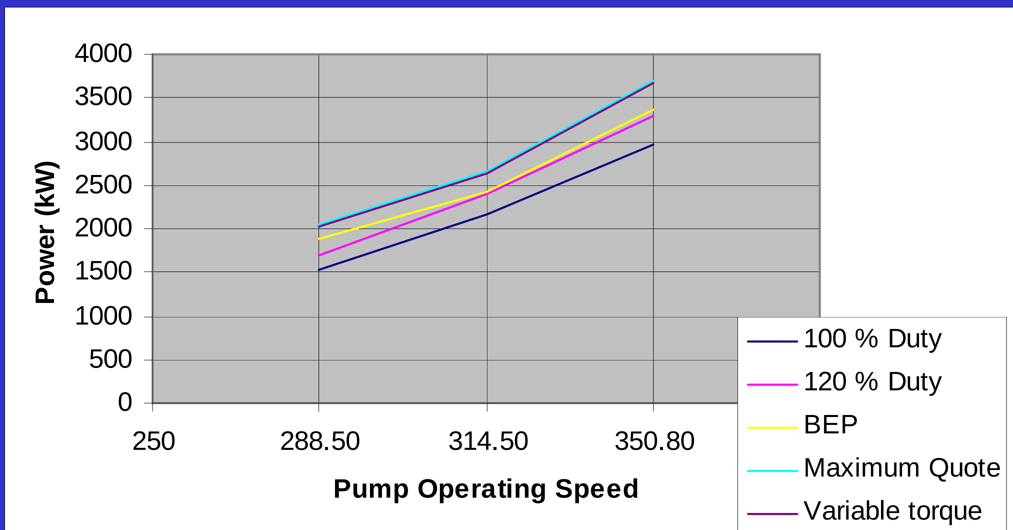
- Permits "Soft Starting"
  - reducing mechanical shock to drive train.
  - Reduces starting voltage drop on the electrical network
- Provides high initial torque to break away torque for silted pumps

Offsetting the phase cycles of multiple piston pumps

- Smoothes flow
- Reduces pressure peaks
- Reduces electrical network current peaks



Slurry Pumping / Hydro-transport

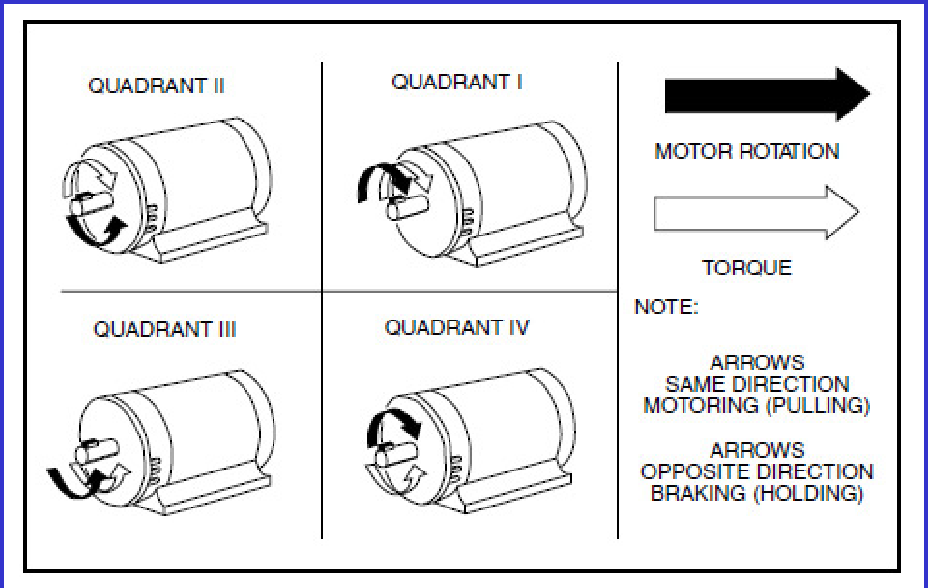


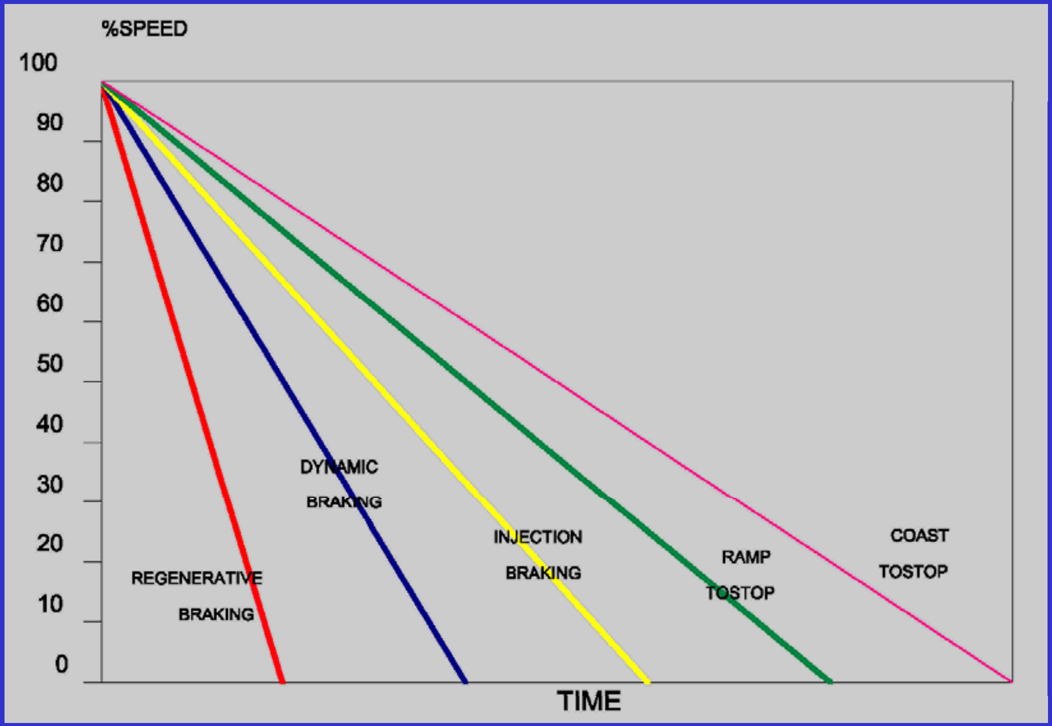
- Slurry pumps are common in mining applications
- Oilsands are unique in combining mining and standard petroleum applications
- Density of the slurry is a consideration in rating the electric drive system
- Potentially an overhauling load - regenerative energy

Regenerative Braking

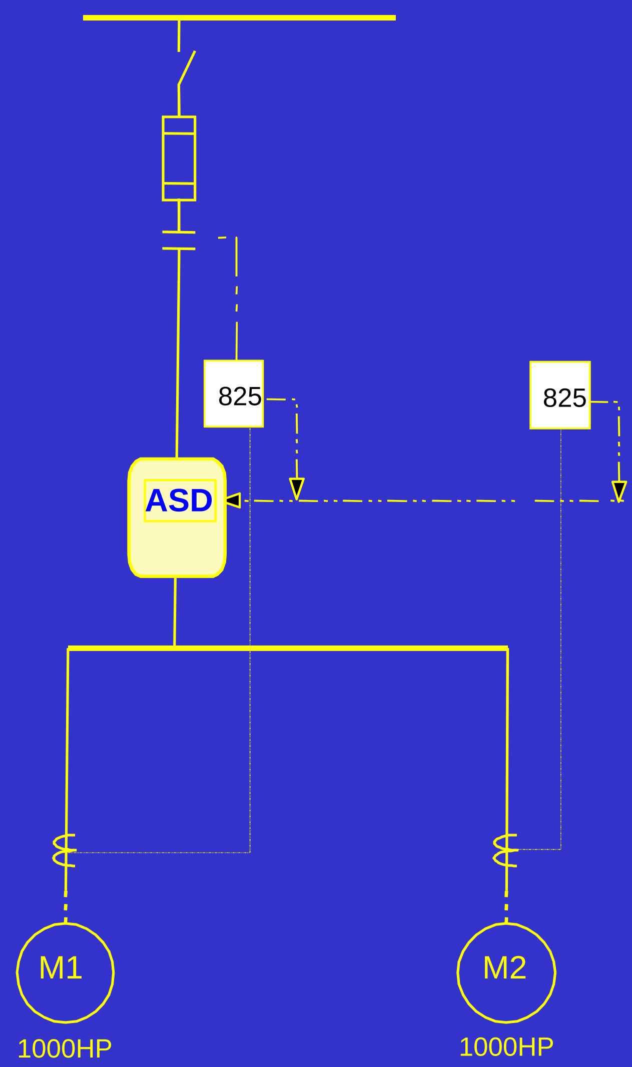
Overhauling loads are the most demanding braking application. Braking energy equal to or even possibly exceeding the motoring requirement are possible in applications such as conveyors, slurry pumps, etc. Regenerative Braking is the best method to deal with this.

An active front end rectifier is required to allow operation in all 4 quadrants





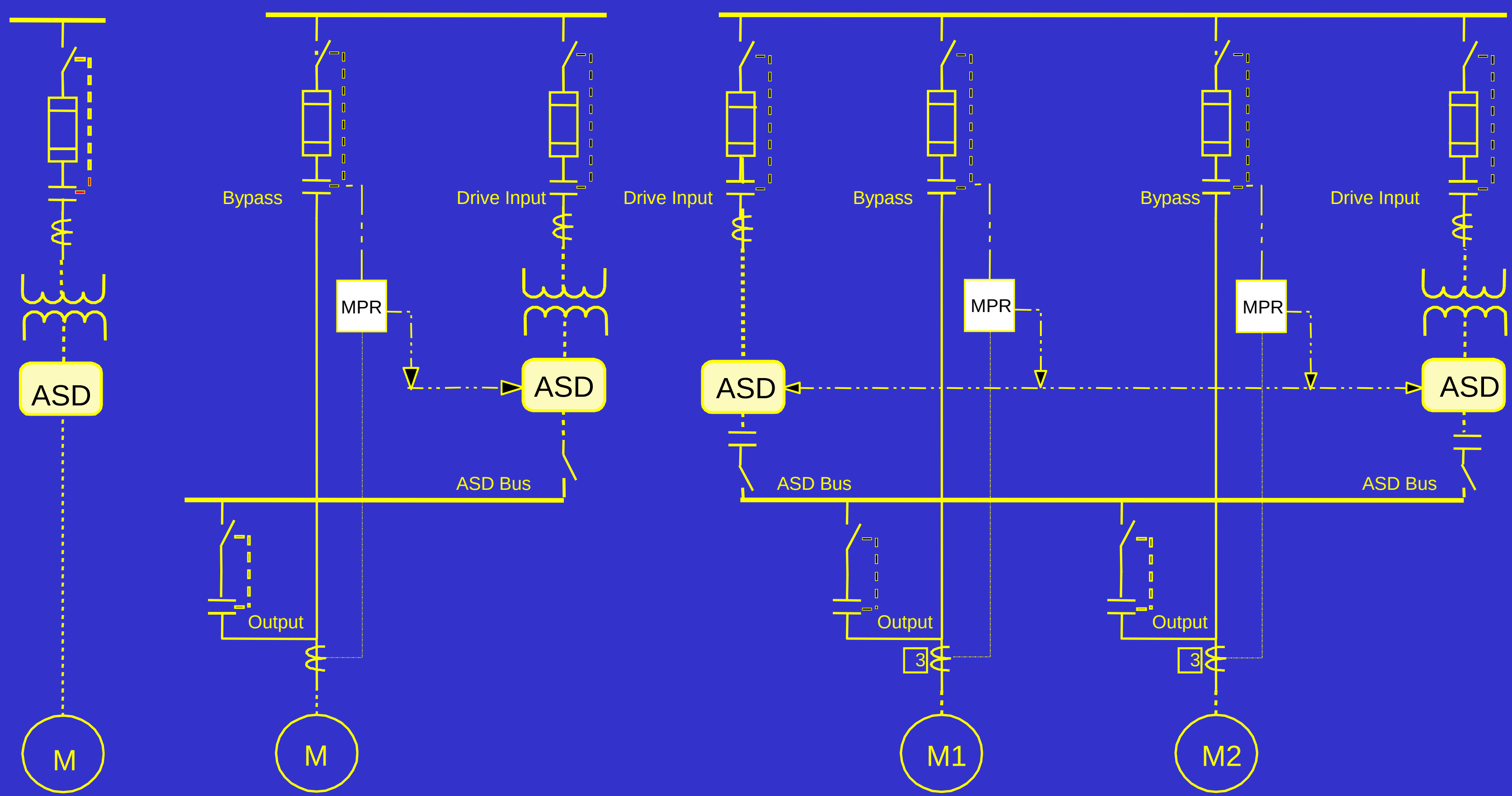
Multi-motor configuration



- Reduced initial cost
- Simultaneous speed control
- Drive sized for total HP
- Motors can be mechanically coupled or separate
  - Mechanically coupled motors must have identical motor characteristics
- Individual motor protection required

Can use output contactors to provide or facilitate possible redundancy

Synchronizing Transfer Configurations

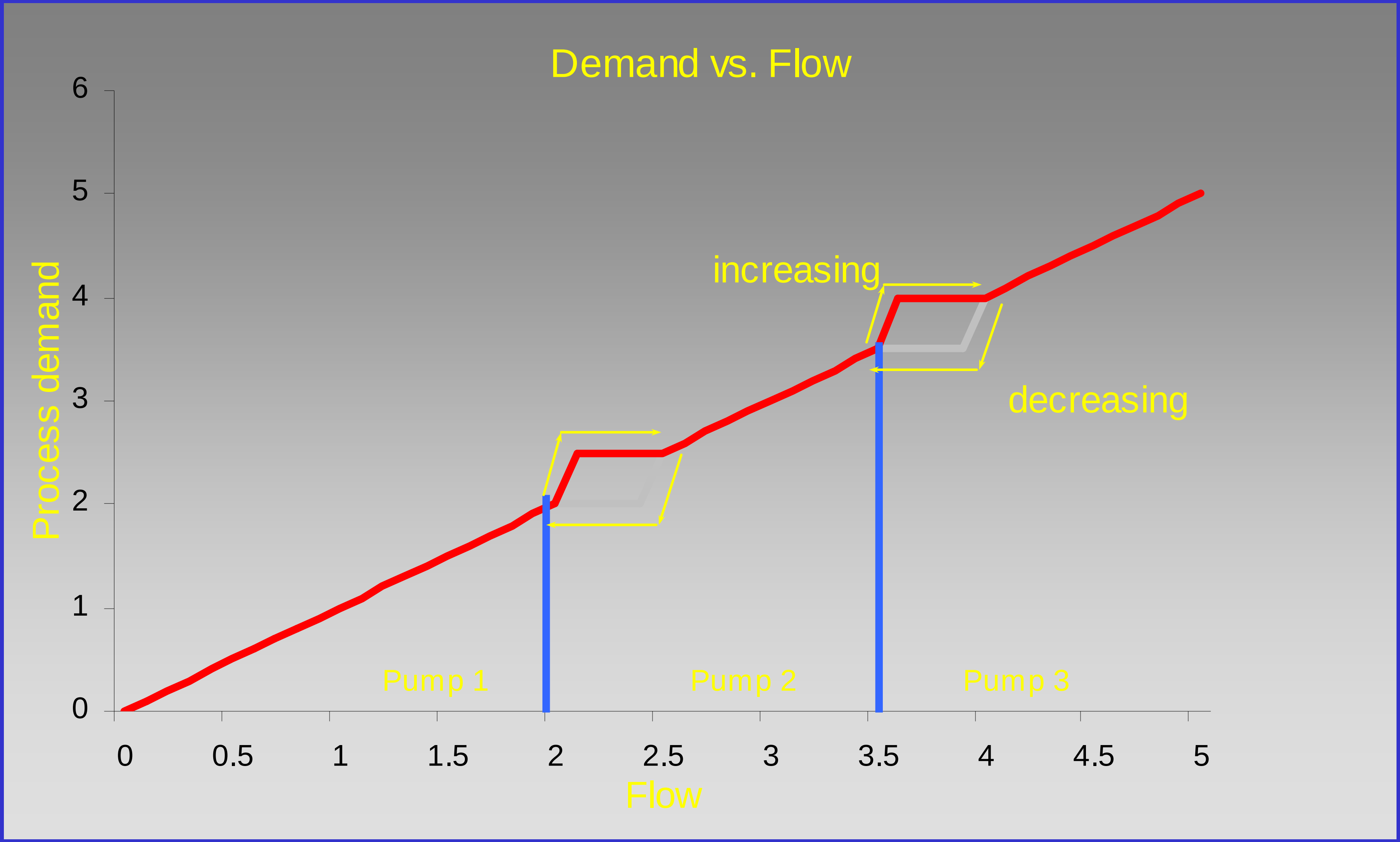


Basic Drive System

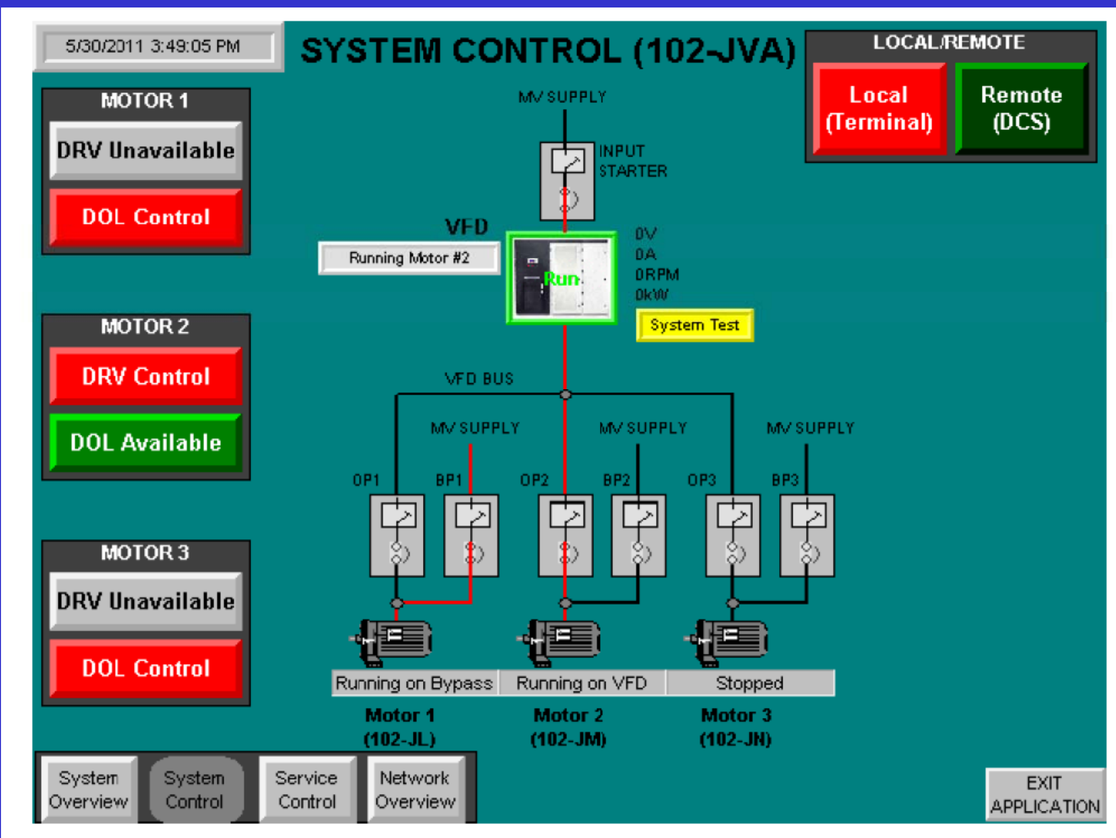
Basic Drive with Synch Transfer Bypass System

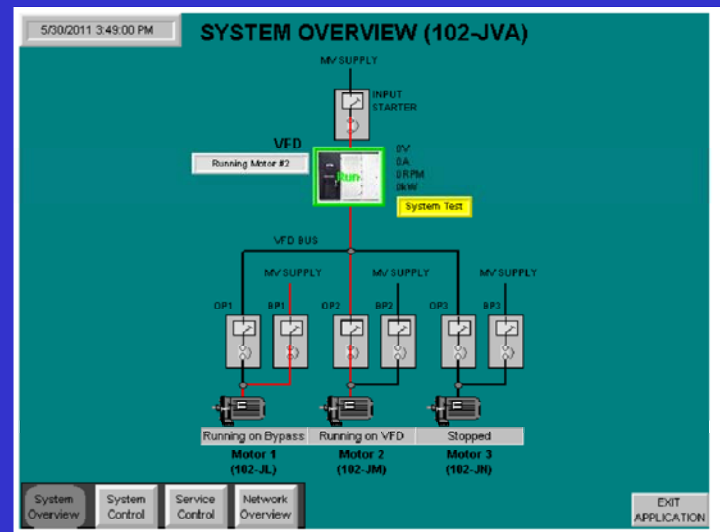
Synch Transfer Bypass System with backup

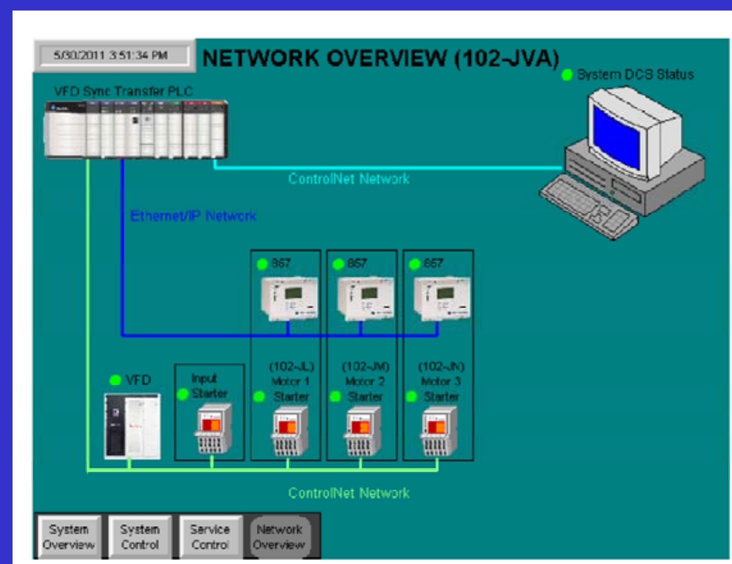
Process Output with Synchronous Transfer



Synchronous Transfer Interface







Marine Applications

Specialty Vessels	Cruise Ferry	Merchant Tankers	Offshore Oil - Gas - Drilling
			

Benefits of Electric Propulsion

Increased Speed

Typical platform supply vessel increased from 10 knots to 14 knots

Reduced Noise / Vibration

18-24 cylinder diesel engine has many pulsating torques that are fed back to generator

Better Handling / Maneuvering

Infinite speed control on thrusters and props

Less space required

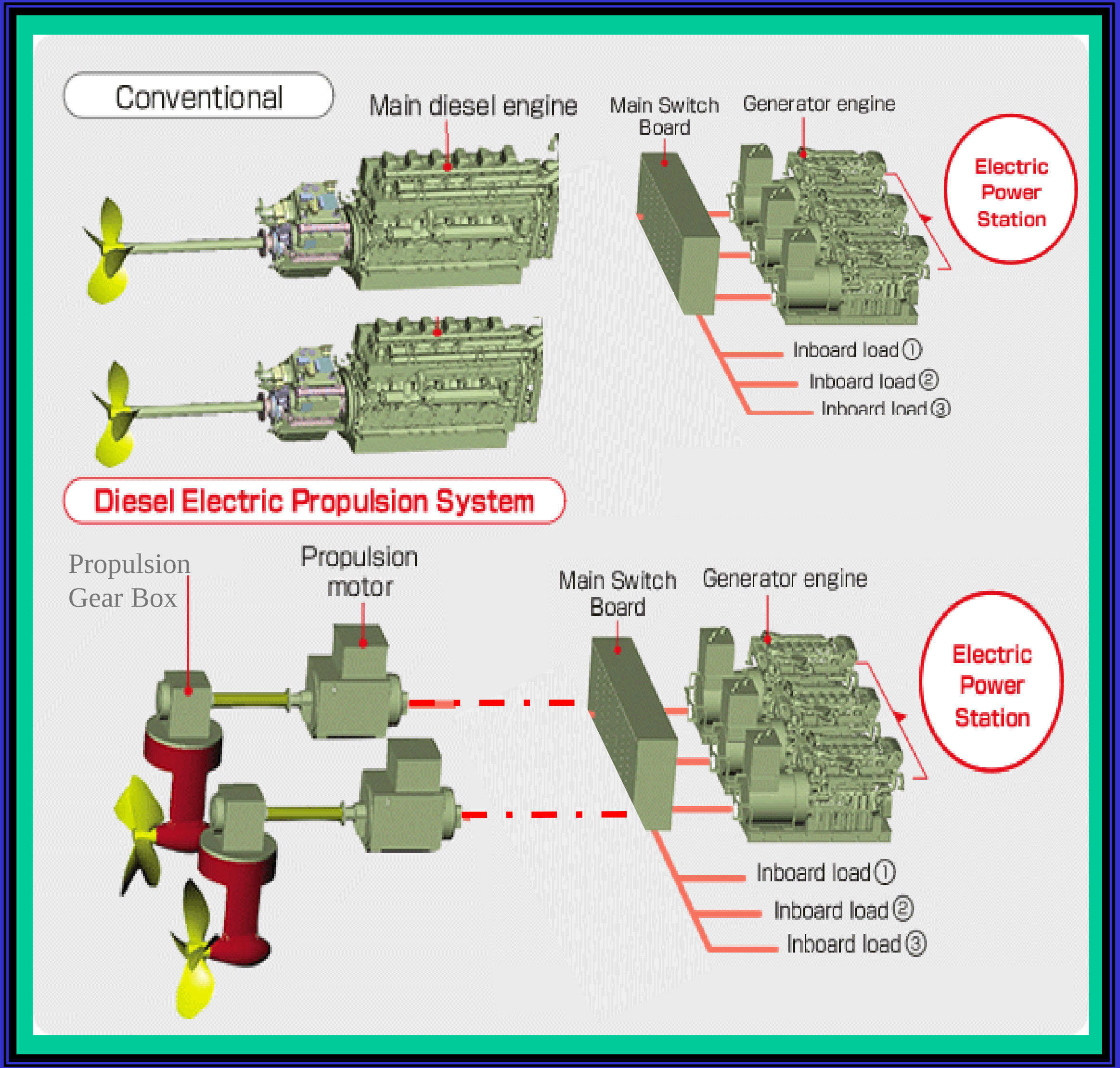
Electric motor much smaller than diesel engine

Less air pollution

No pollutants from electric motors versus diesel

Easier to comply with Marpol restrictions

Scaled generator loading with power management system



Benefits of Electric Propulsion

Eliminate mechanical pitch control

- Reduced maintenance
- Higher efficiency

Greater flexibility in ship layout

- More space in hull

Lower Fuel Consumption

- Elimination of diesel engines
- Scaled electrical generation

Higher Reliability

- Less mechanical maintenance
- 10 year MTBF - electric drive & motor

Higher Efficiency

- 96% efficiency for electric drive and motor

Azipod Cruise Main Propulsion & Thruster Systems

Antarctic Research Vessel

Main Propulsion System: 2 x 7000 KW
Synchronous Low Speed Direct to Drive AFE
Power Converters 6300V
Ac Brushless Exciter – Dual Redundant
Certification: RMRS – ACCU – Ice Class 7

Project – Up date

Project Up date

Electric Submersible Pump

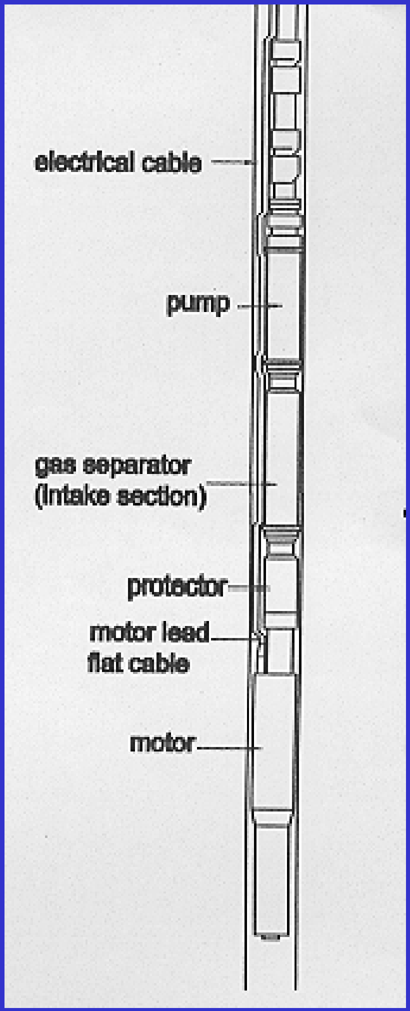
- Centrifugal or progressive cavity pump directly driven by a three phase induction motor

- Specialized construction
  - Low inertia
  - High starting torque
  - Assemblies can be 35m in length while less than 12 to 17cm in diameter

- Extreme operating environment
  - High temperatures and pressures
  - Corrosive materials pumped
  - High sand content common

- Rotor shaft must have a small cross sectional diameter by design therefore has limited torque capability

- Additional protection considerations relative to more conventional horizontal mounted systems



Base ASD Design Considerations & Objectives

- High Availability
- Low capital cost
- Small footprint
- Higher voltages & ratings
- Low harmonics
- Motor Friendly – dv/dt, heating, CMV
- Simple design
- Ease of use
- Ease of installation

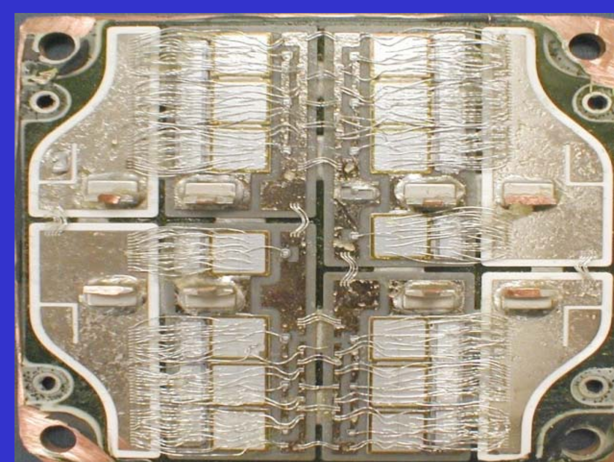
- Low Total Cost of Ownership
- High Efficiency
- Power Factor
- Dynamic Response
- Features

Cost Effective

Performs as expected

Basic ASD Design Considerations

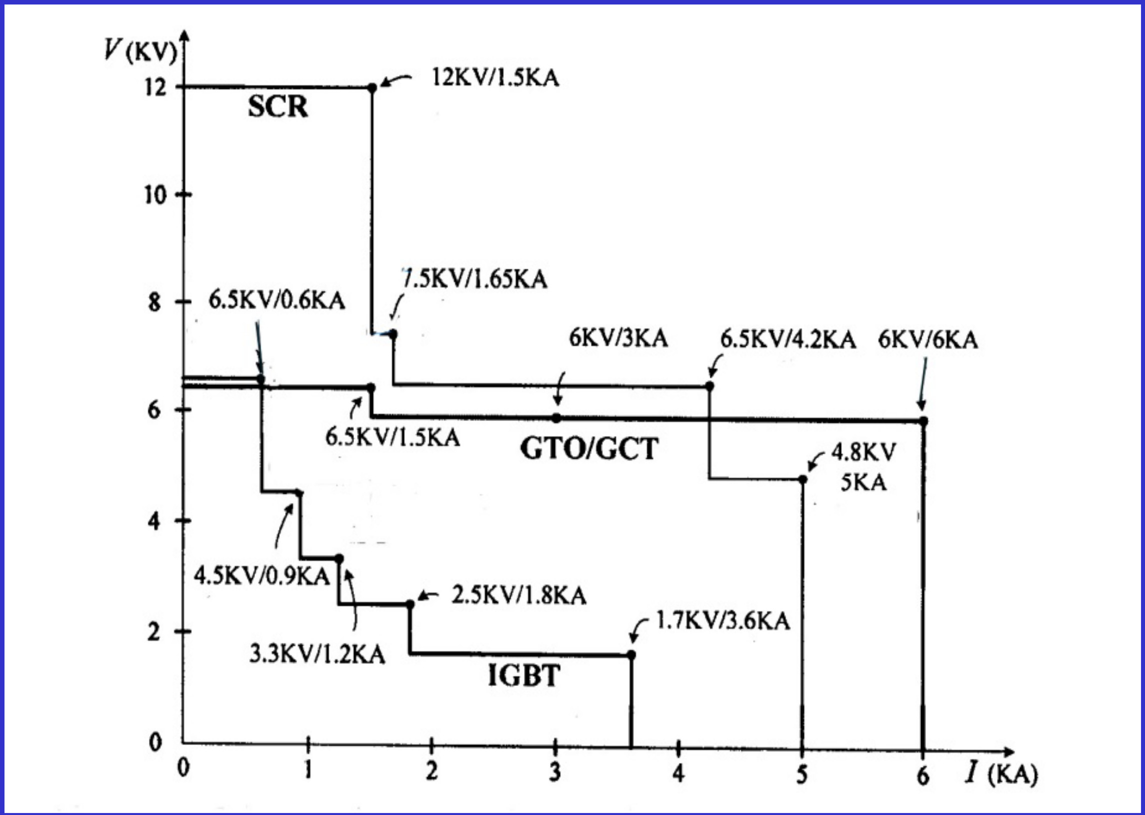
- Wide variety of semi-conductors available
  - Diode
  - SCR
  - IGBT
  - IGCT
  - SGCT
- Each has its own set of design characteristics - strengths / weaknesses



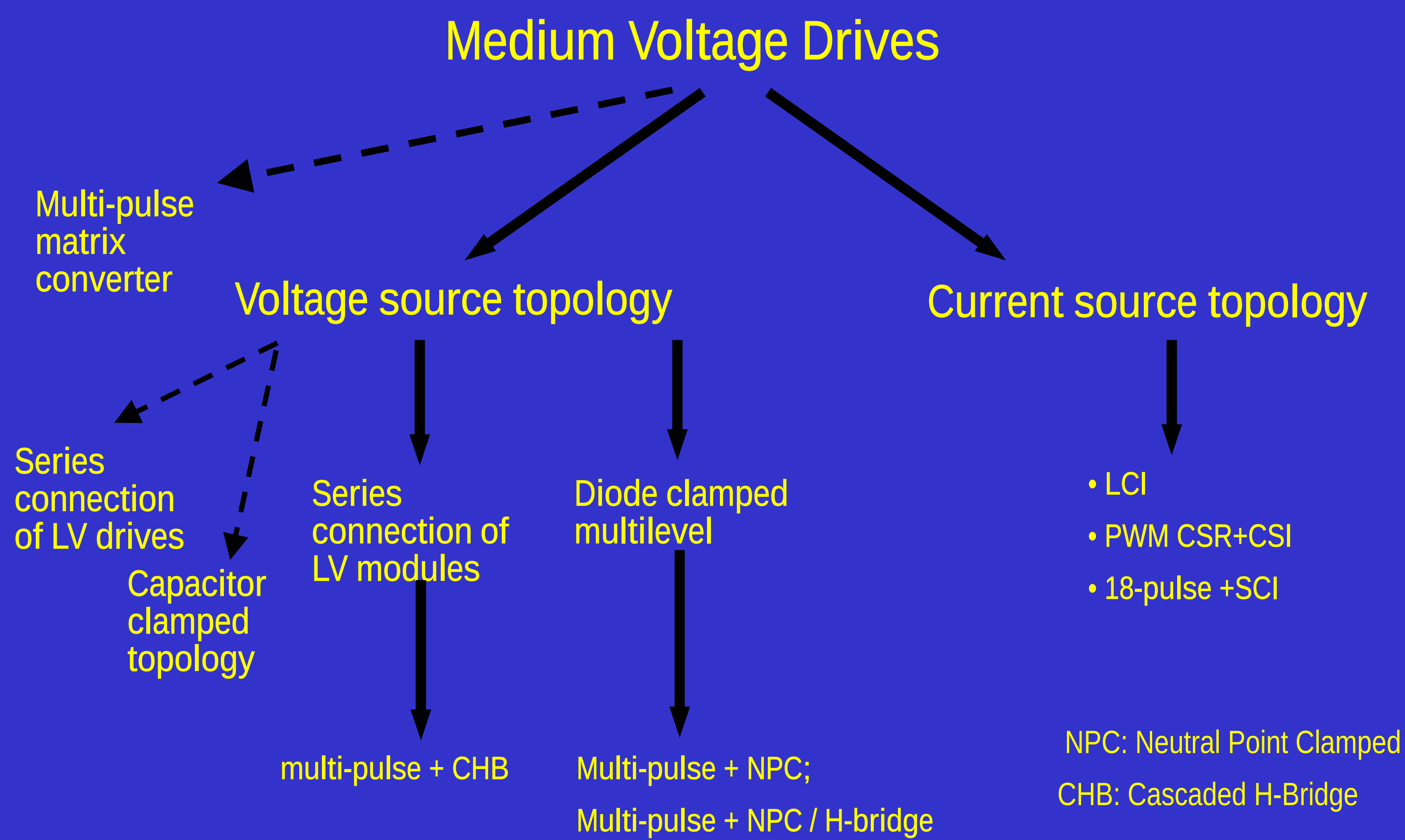
Semiconductors

Semiconductor characteristics determine ASD design & topology

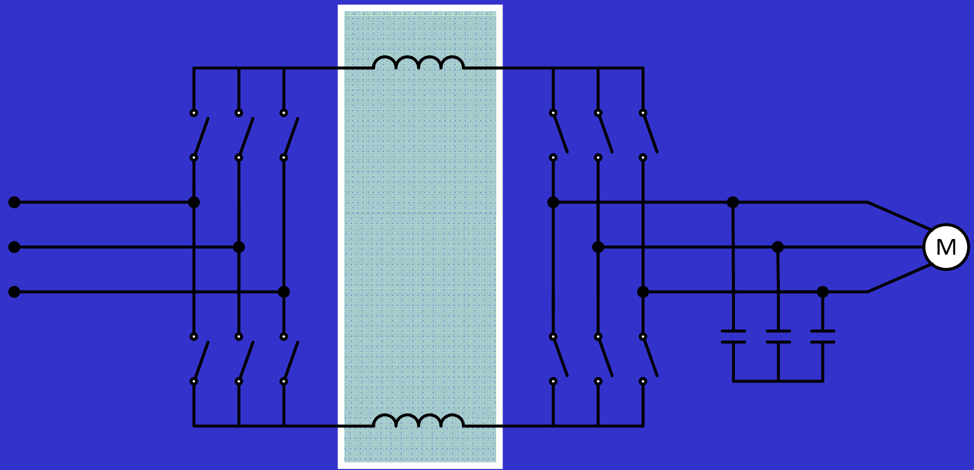
- Voltage and current ratings
  - # of devices
- Device utilization
  - Series or parallel
- Device FIT (failure in time) rate
  - Need for redundancy
- Device failure mode
  - Shorted or open
  - Rupturing or non-rupturing
- Switching Speed
  - PWM & other switching techniques
  - Size of ASDS

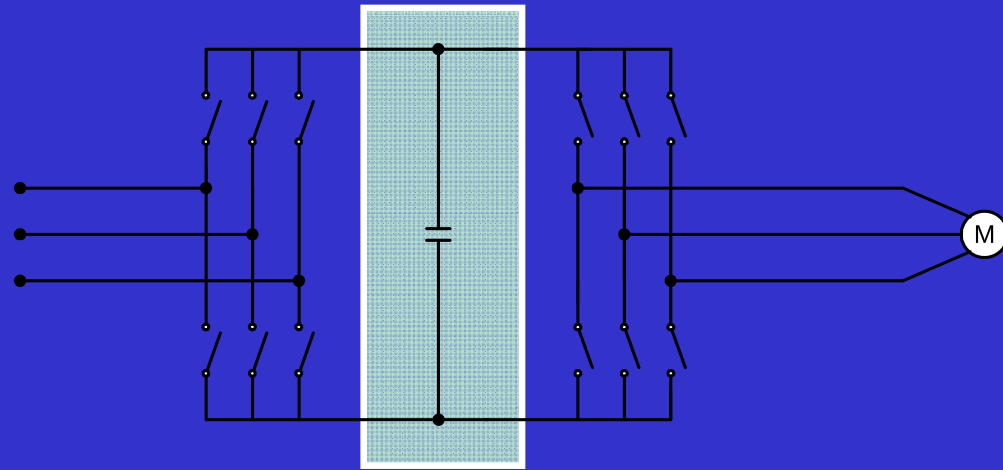


Topology fundamentals: classification

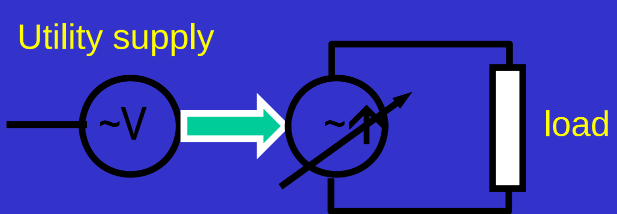


Topology fundamentals: CSI & VSI





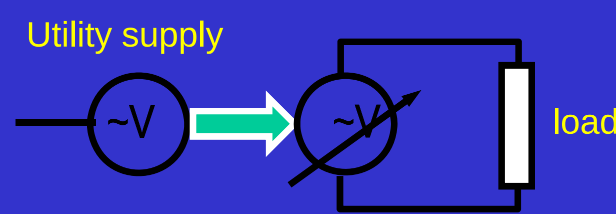
Current Source Topology



Active phase controlled or PWM rectifier

Stiff current supply @ DC link

Voltage Source Topology



Passive or active phase controlled

Stiff voltage supply @ DC link

Topology Fundamentals - Rectifier

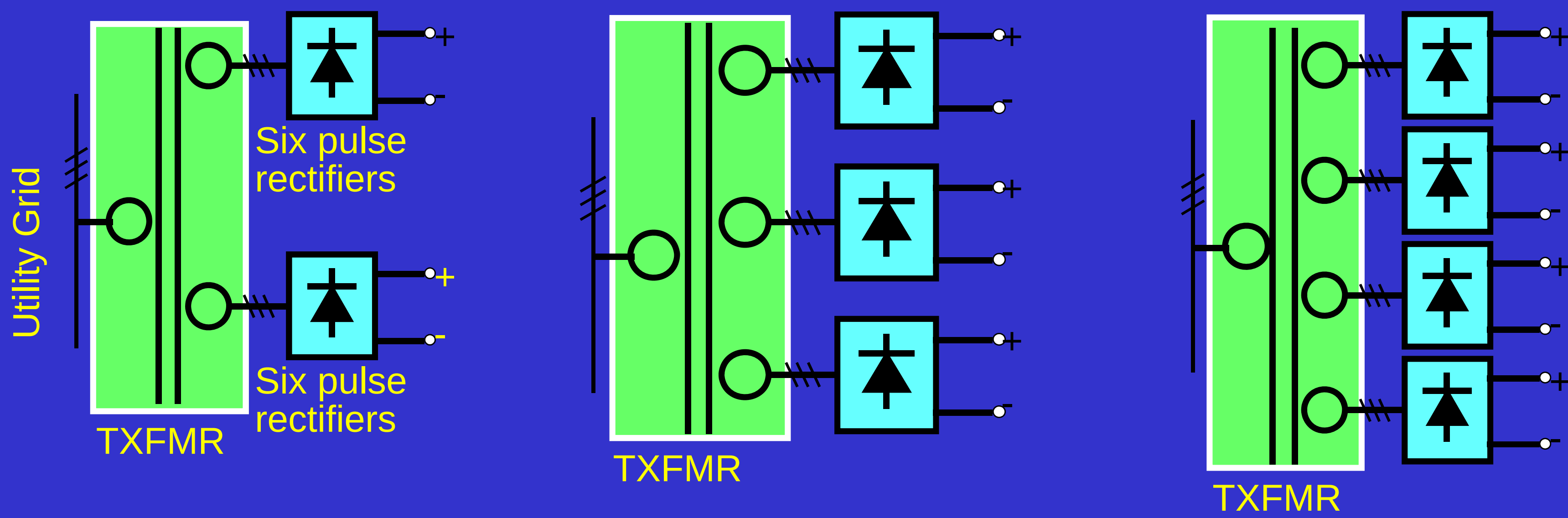
Passive Front End

- Typically a diode bridge
- Simple device
- Power factor – 0.95 to 0.955

Active Front End

- Rectifier is a gated device
- Allows 4 quadrant operation
- Involves the use of SCRs, SGCTs or equivalent devices
- Power factor 0.98 to unity (VT)
- Harmonic mitigation techniques by firing and regenerative braking are possible

Topology Fundamentals - Rectifier



(a) 12-pulse rectifier

$\delta = 30^o$

(b) 18-pulse rectifier

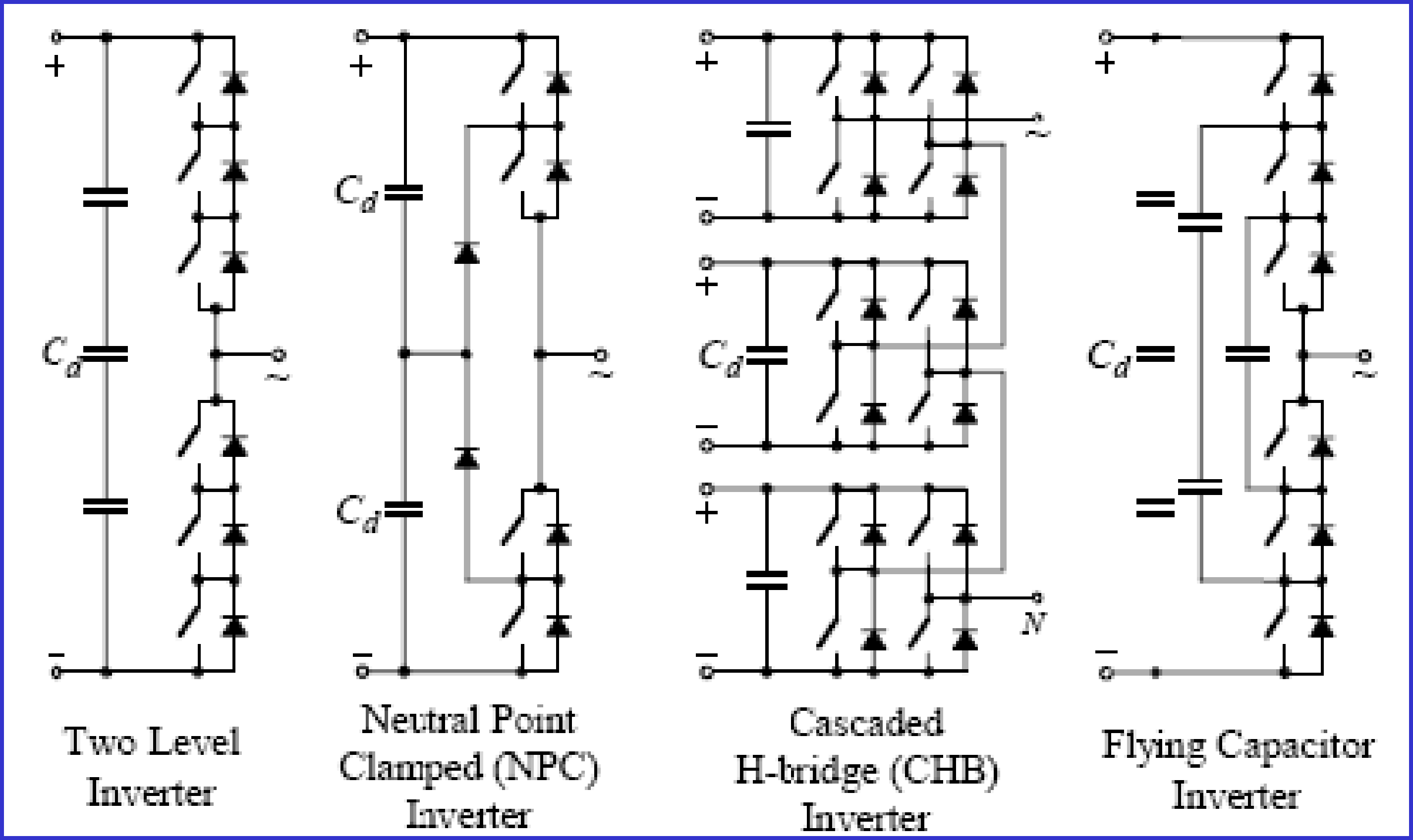
$\delta = 20^o$

(c) 24-pulse rectifier

$\delta = 15^o$

Transformer is also used to deal with common mode voltage

Topology Fundamentals - Inverters



- **Higher output voltage w/o devices in series**

Topology Fundamentals – Voltage Source Drives

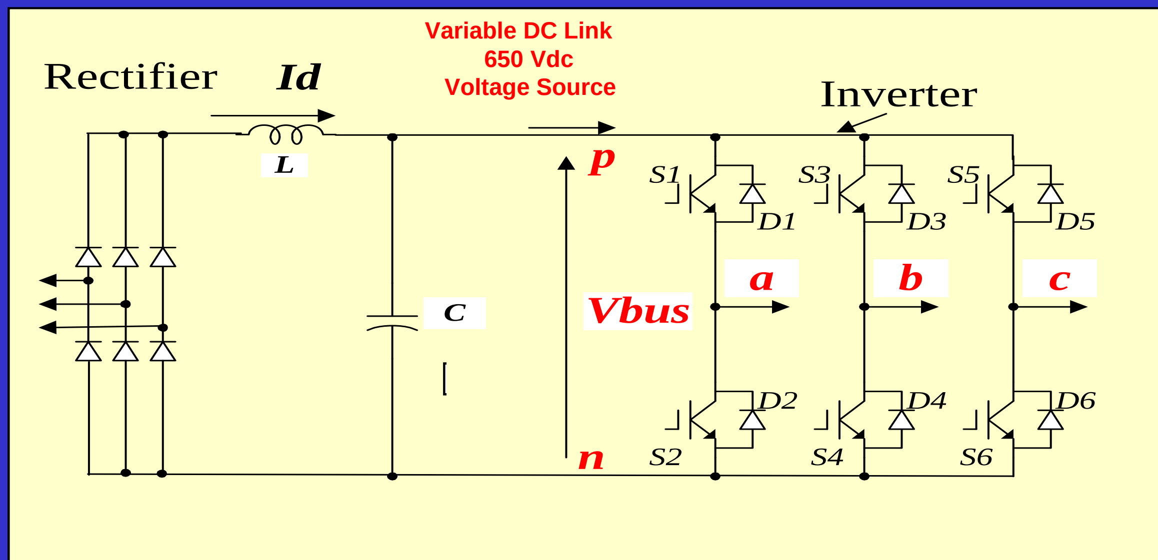
Variable Voltage Inverter (VVI)

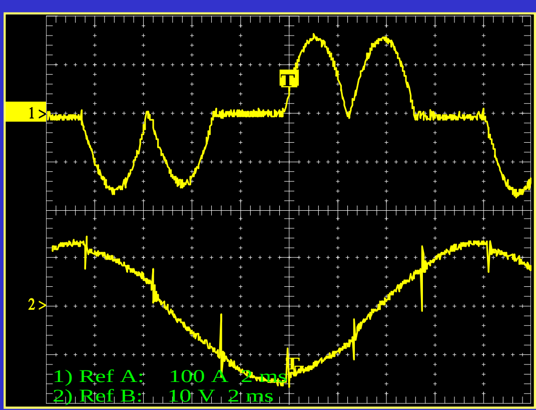
Voltage Source Inverter (VSI – PWM)

Multilevel Voltage Source Inverter (MVSI)

Multilevel Voltage Source Cascaded H bridge (CHB)

Topology Fundamentals – Voltage Source Drives



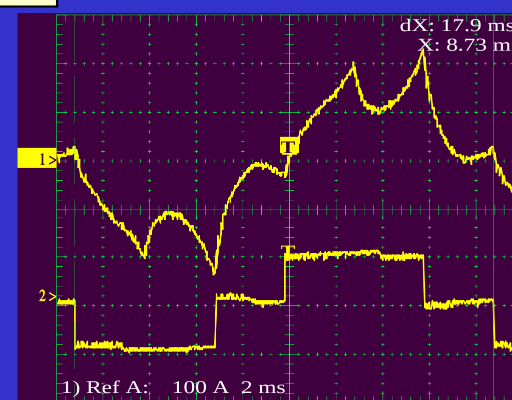


480 Volt Input
Top: Current waveform
Bottom: Voltage waveform

<u>LV VVI 6 Step Base Characteristics</u>

Input:
SCR bridge rectifier
Variable DC Link bus voltage

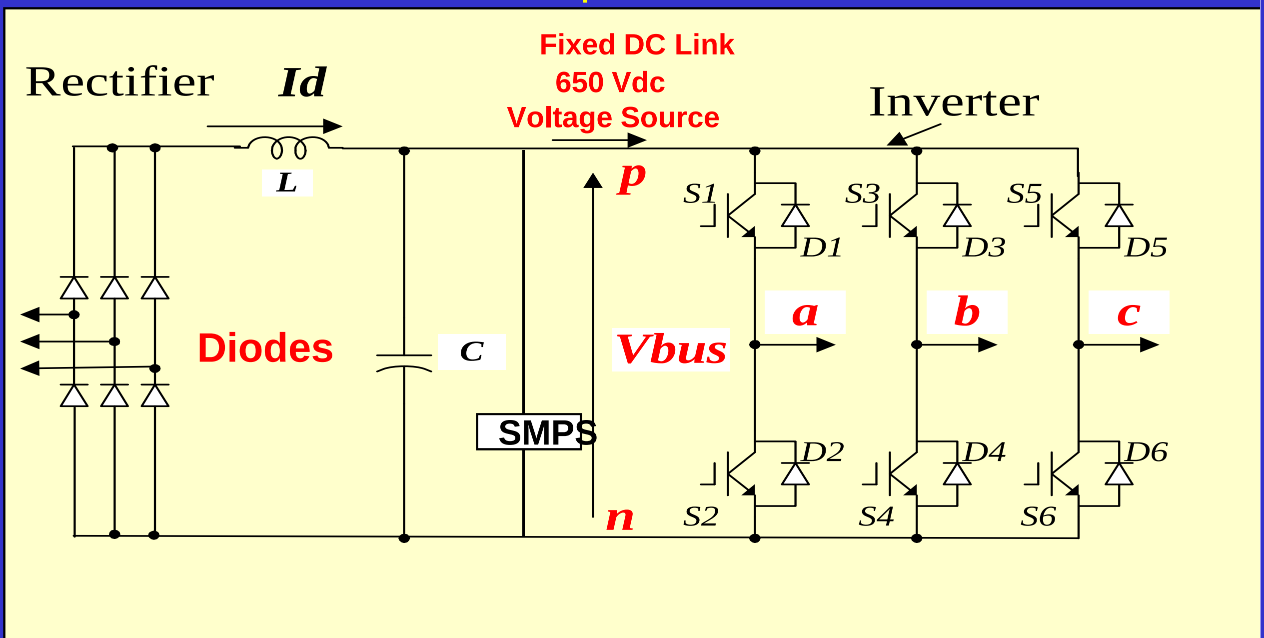
Output:
Inverter switches to obtain required waveform orientation

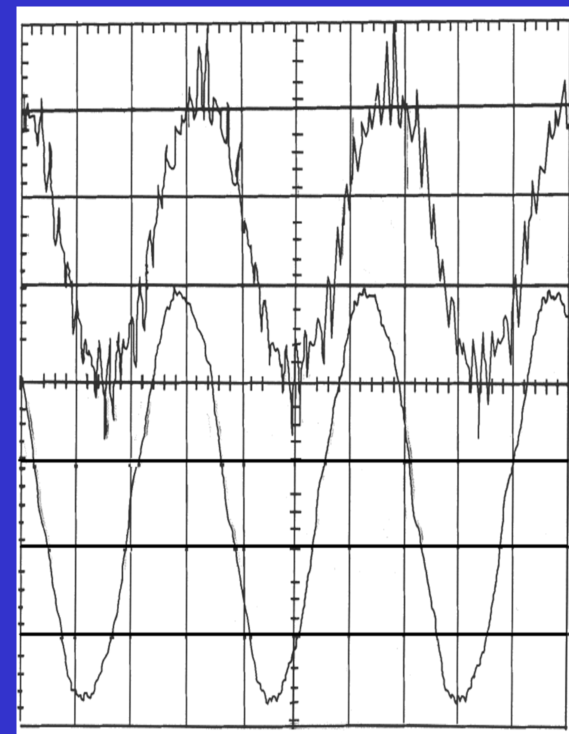


480 Volt Output
Top: Current waveform
Bottom: Voltage waveform

VSI – PWM 2 Level

6 Pulse Rectifier, DC Link capacitor & IGBT Inverter





480 Volt Output
Top: Current waveform
Bottom: Voltage waveform

LV VSI PWM 2 Level Base Characteristics

Input:

•Diode bridge rectifier typically 6 pulse

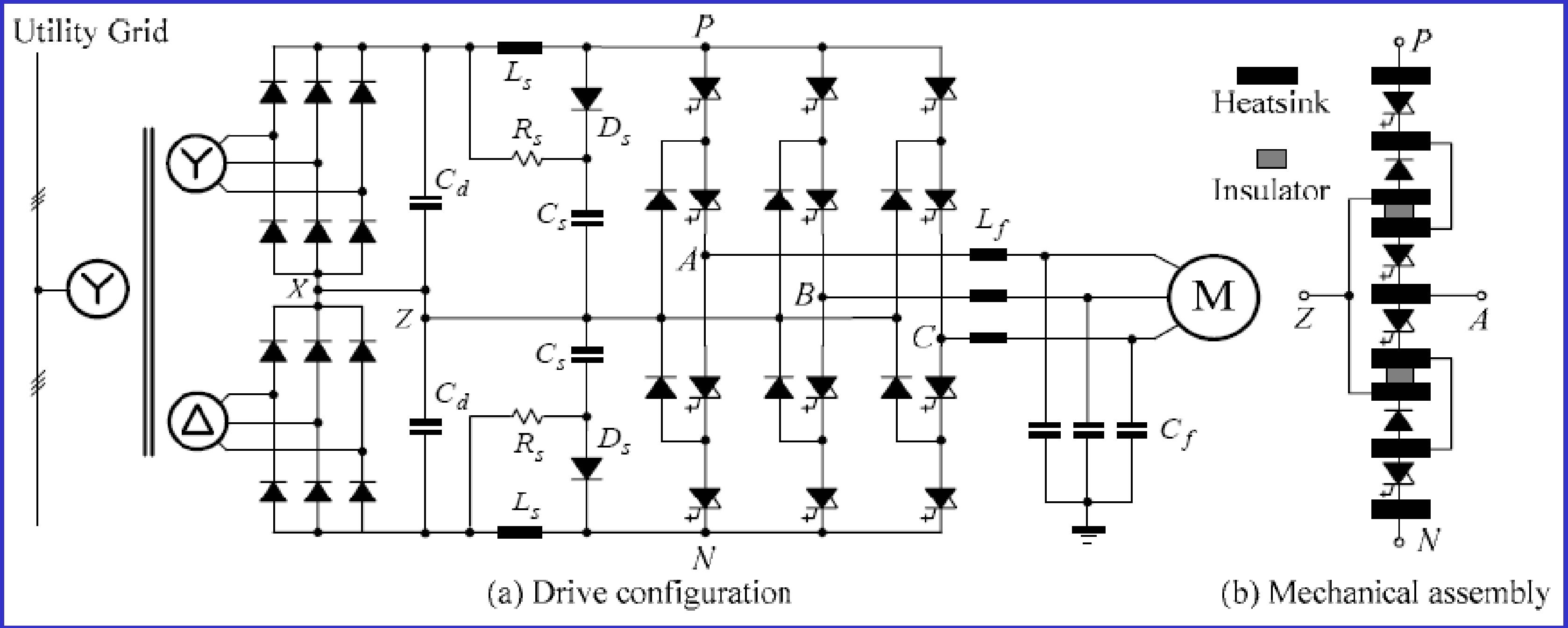
•Fixed DC Link bus voltage

Output:

•PWM inverter switches @ high frequencies (2 – 10 kHz) to obtain required output voltage and harmonic elimination

• Most common LV technique employed in industry presently

VSI – PWM 3 Level



VSI-PWM 3 Level with Output Filter Topology

Tuned LC output Filter To reduce Voltage Stress design – motor specific

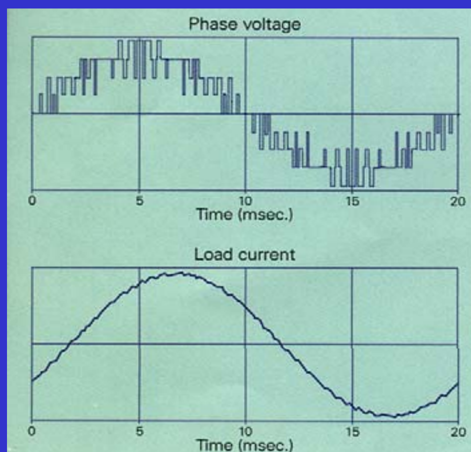
12 Pulse Rectifier

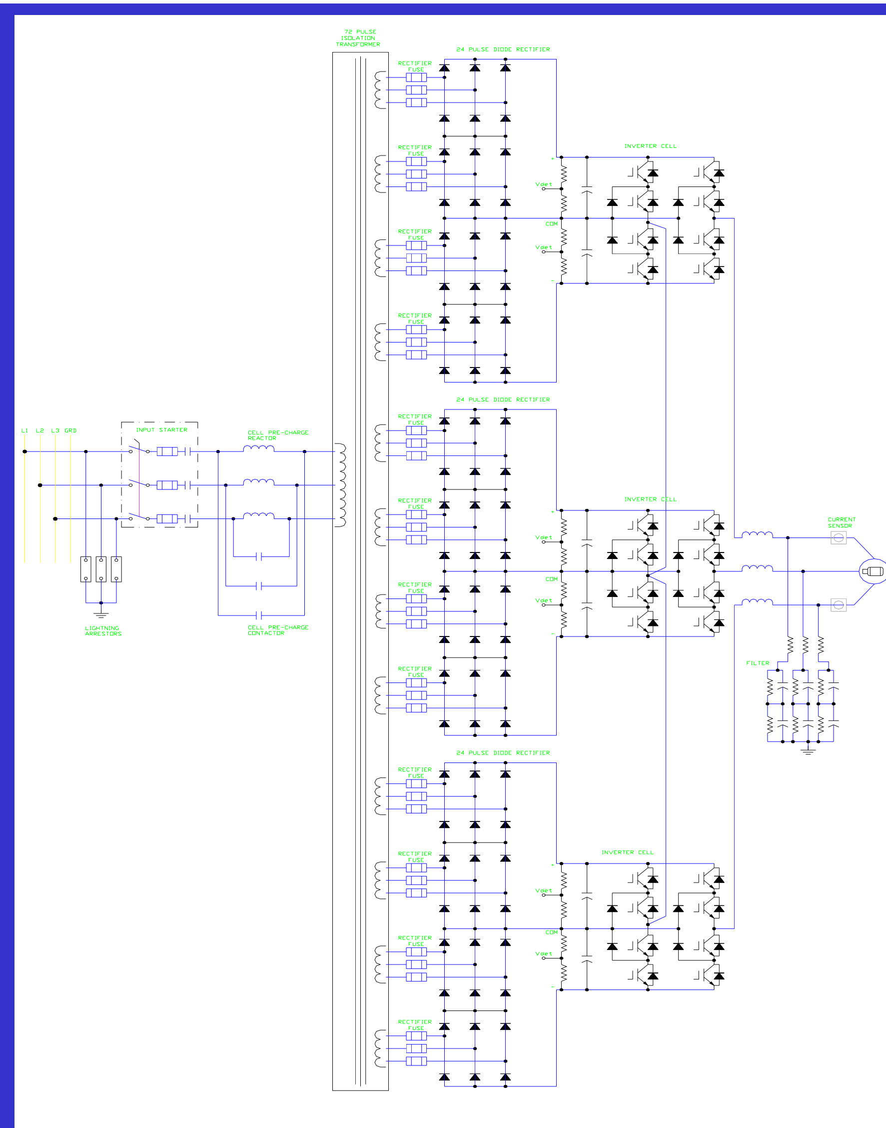
3 Level Neutral Point Clamp Inverter

Medium Component Count

GTO or IGCT Power Devices

VSI – PWM Multi-Level Inverter





VSI-PWM Multi Level – 5 Level shown

Medium to High Component count
- 36 fuses, 84 diodes, 24 IEGTs, OP filter & reactor

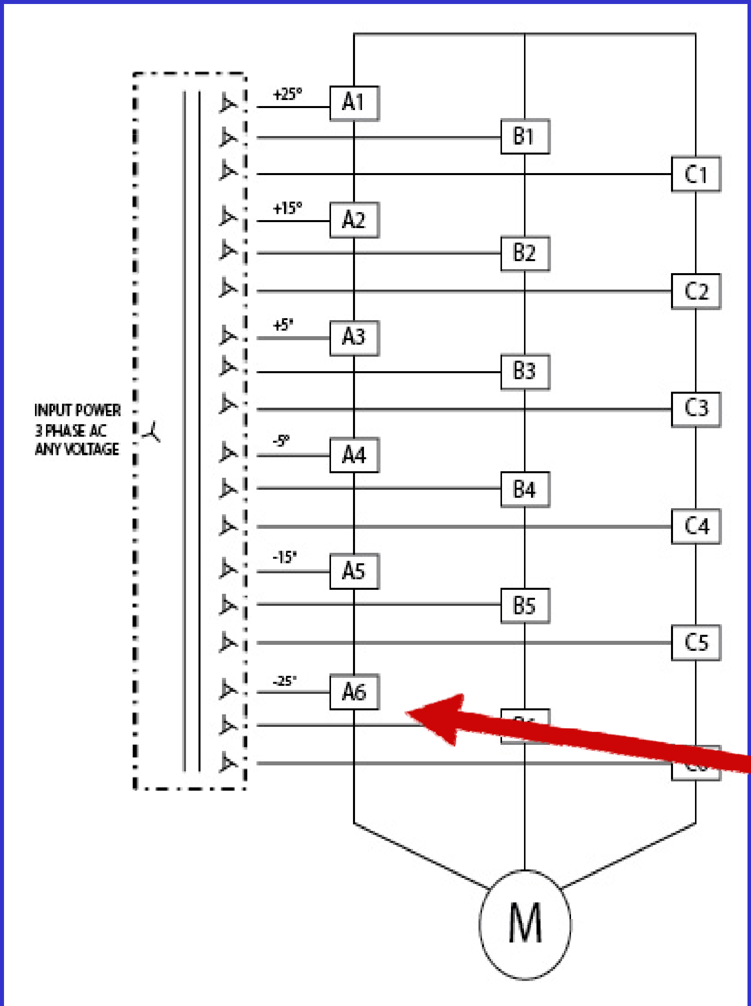
May require a new motor with up graded insulation system or output filter

Cable length restrictions can be extended with use of output filter

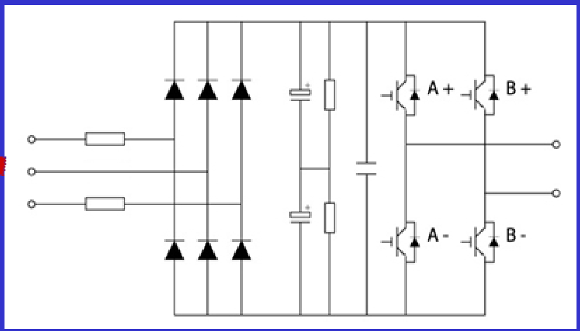
No option for device redundancy

VSI - Multi-Level Cascaded H Bridge

Multi-Level Cascaded H Bridge



- Low line THD
- Modular design
- Ideally suited for higher voltages – 13.8 kV
- High component count – fuses, devices
- Multi-winding close coupled isolation transformer



Topology Fundamentals – Current Source

Load Commutated Inverter (LCI)

Capacitor Assisted Current Source Inverter (CACSI)

Current Source Inverter (CSI – PWM GTO) – 1989 to 2000

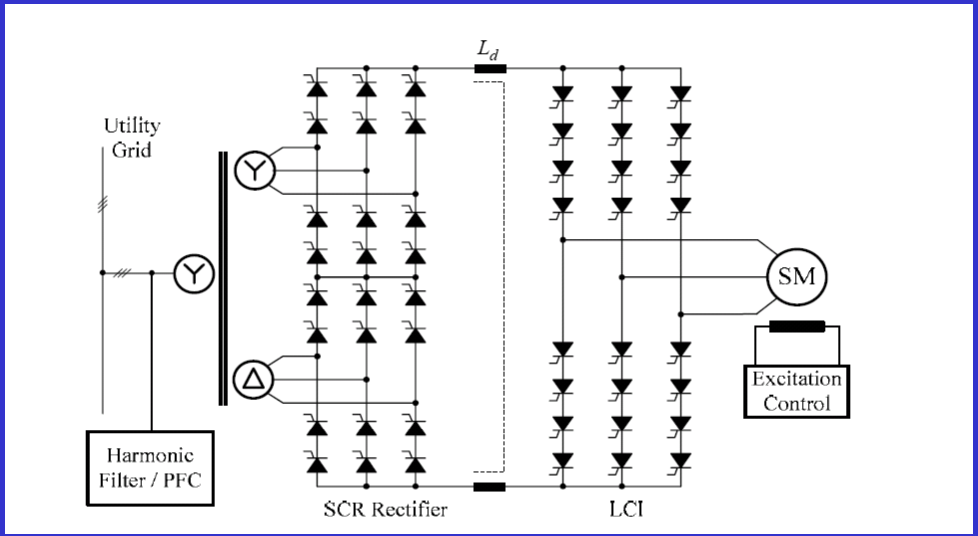
Current Source PWM Rectifier & PWM Inverter (CSI & CSR PWM)

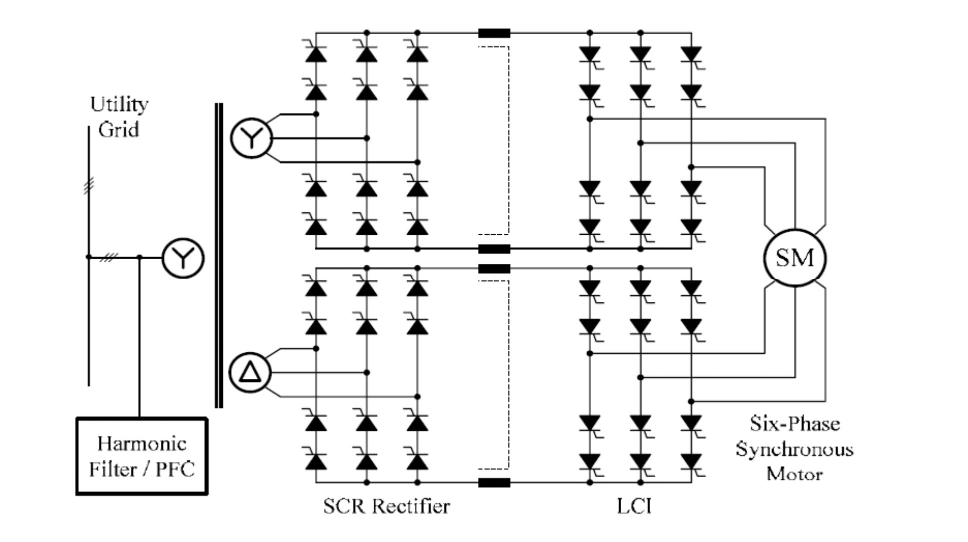
- Introduced in 2000
- CMVE addition in 2004

CSI - LCI

Load Commutated Inverter (LCI)

- Still in use
- Low cost, high efficiency, reliable, large ratings, regenerative braking
- 12 pulse rectifier and either a 6 or 12 pulse inverter
- Synchronous motor required
- High output torque pulsations, slower response and linear power factor with speed
- Typically requires HF / PFCC unit to address power factor and harmonics





CSI - CACSI

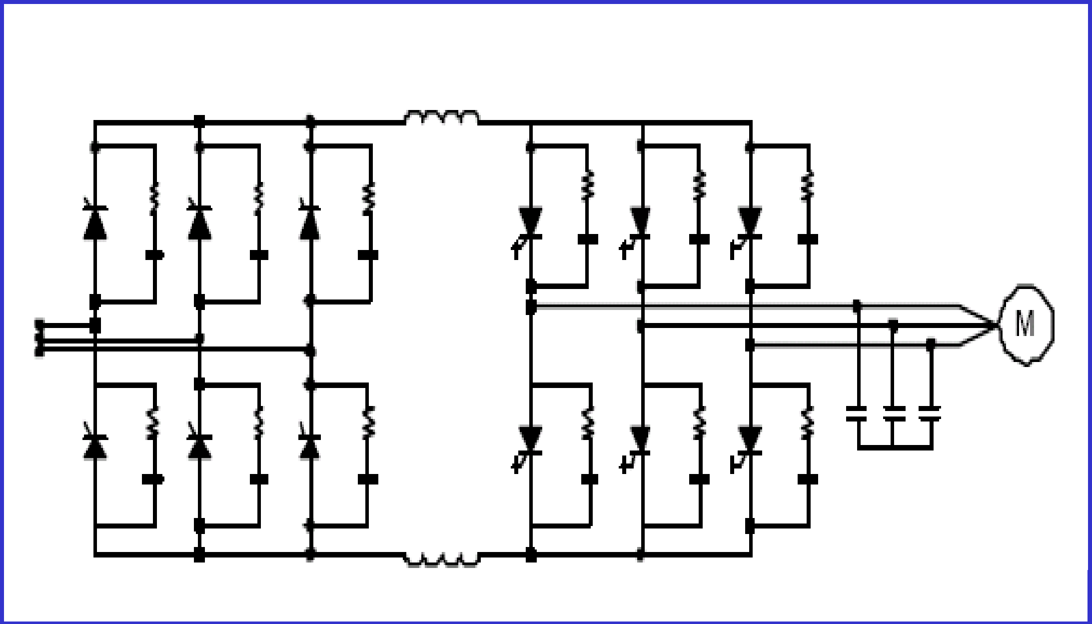
Capacitor Assisted Current Source Inverter (CACSI)

- Introduced in late 70’s early 80’s
- SCR rectifier – 6 or 12 pulse
- Large DC link inductor
- SCR inverter, a large output filter capacitor is required > 1 pu
- Capacitor assists the SCR commutation of the inverter at high speeds
- A crowbar or commutation circuit is used to commutate the SCRs of the inverter at low speed
- Limited effective speed range – 30 to 60 hz
- No PWM techniques were employed
- Required HF / PFCC unit
- Many still in service

CSI - PWM

CSI-PWM - GTO

- Introduced in late 1980’s
- SCR rectifier – active front end
- DC link inductor (1.0 pu)
- GTO inverter (PWM firing)
- Output capacitor (0.4 – 0.6 pu)
- Rectifier choices
  - 6 pulse
    - (line reactor or iso txfmr)
  - 12 pulse (iso txfmr)
  - 18 pulse (iso txfmr)



Inherently regenerative

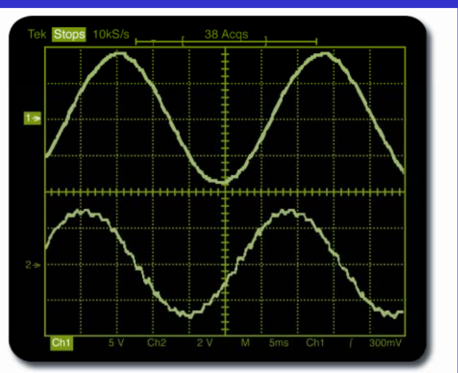
Simple topology

Durable design – fault tolerant

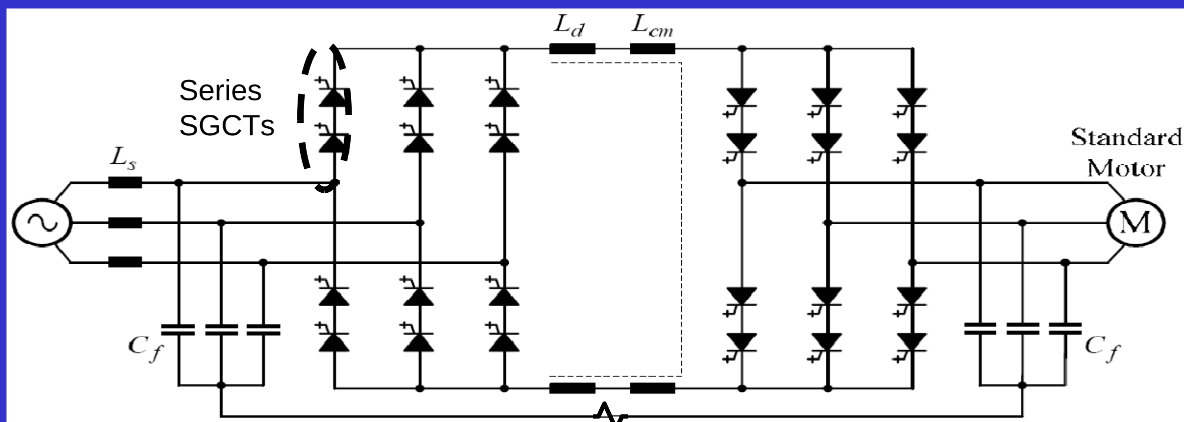
Line reactor version required motor insulation suitable to address CMV

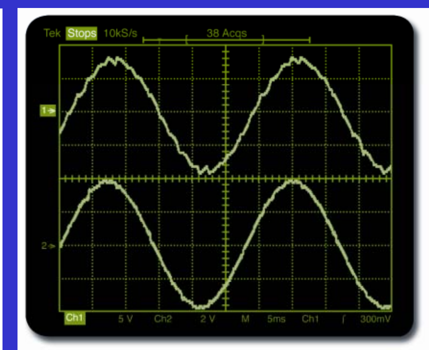
CSI – PWM - CMVE

CSR+CSI with Common Mode Voltage Elimination



MV Input – 2.4 to 6.6 kV
Top: Current waveform
Bottom: Voltage waveform





MV Output – 2.4 to 6.6 kV
Top: Current waveform
Bottom: Voltage waveform

- Introduced in 2000, CMVE addition in 2004
- Does not require an isolation transformer
- Inherent regenerative braking
- Near-sinusoidal input & output voltage waveforms
- Common mode voltage addressed within drive

- Simple power structure – High MTBF
- Low component count
- Commonality of parts – rectifier same component as inverter
- Virtually unlimited cable distances between drive and motor

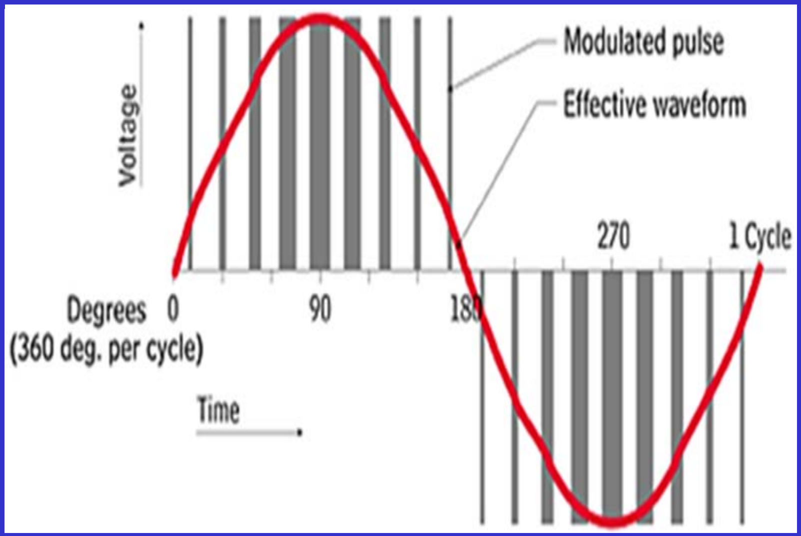
Industry News & Trends

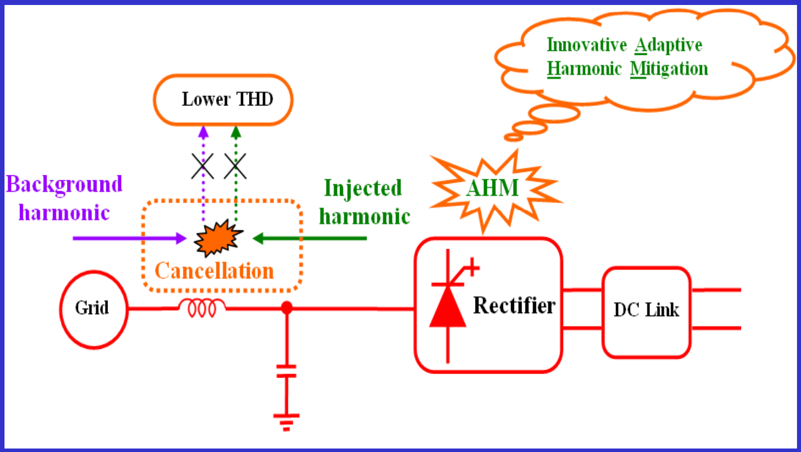
- Increased use of ASDs
- Less Gas compression electrification
- Class H bridge patent expires April 2014
- Cooling – minimize air conditioning
- New topologies – AFE & transformer-less
- Cross pollination of topologies

Active Front End

Active Front End

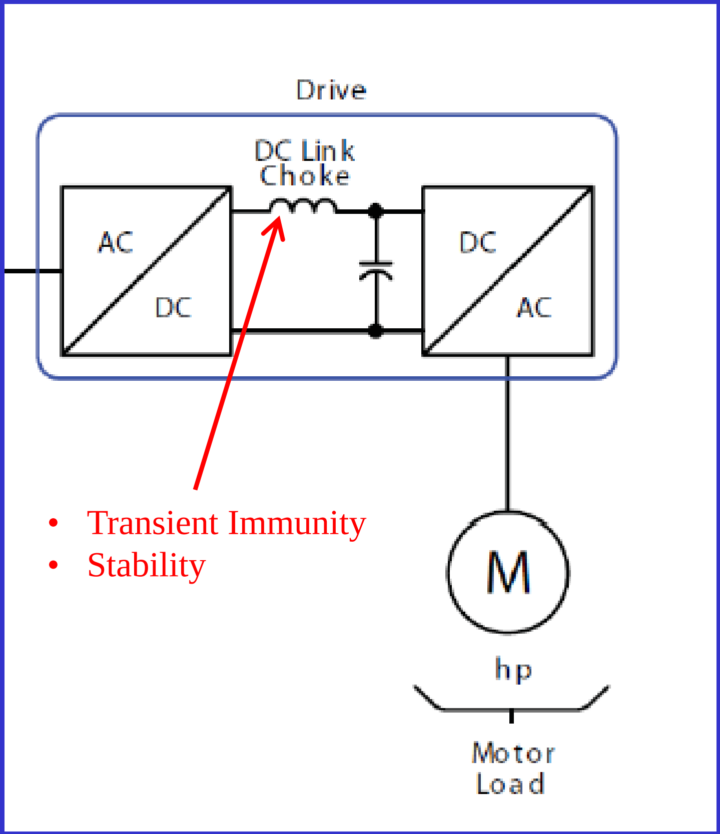
- •Several topologies which had been passive rectifiers are coming out with AFE options
- •Elimination of drive isolation transformer – reduction in associated losses, size and weight
- •Low AC input harmonics
  - Pulse Width Modulation
  - Selective Harmonic Elimination
- •Increased versatility
  - 4 quadrant operation
  - Protective gating strategies
  - Active power factor control
  - Possible active harmonic mitigation (future)





Cross Pollination of Technologies

- Facets of different designs may improve performance of existing topologies
- Active Front End technology
- Introduction of inductors in capacitive DC link arrangements to improve transient immunity and ASD overall stability



Industry News & Trends

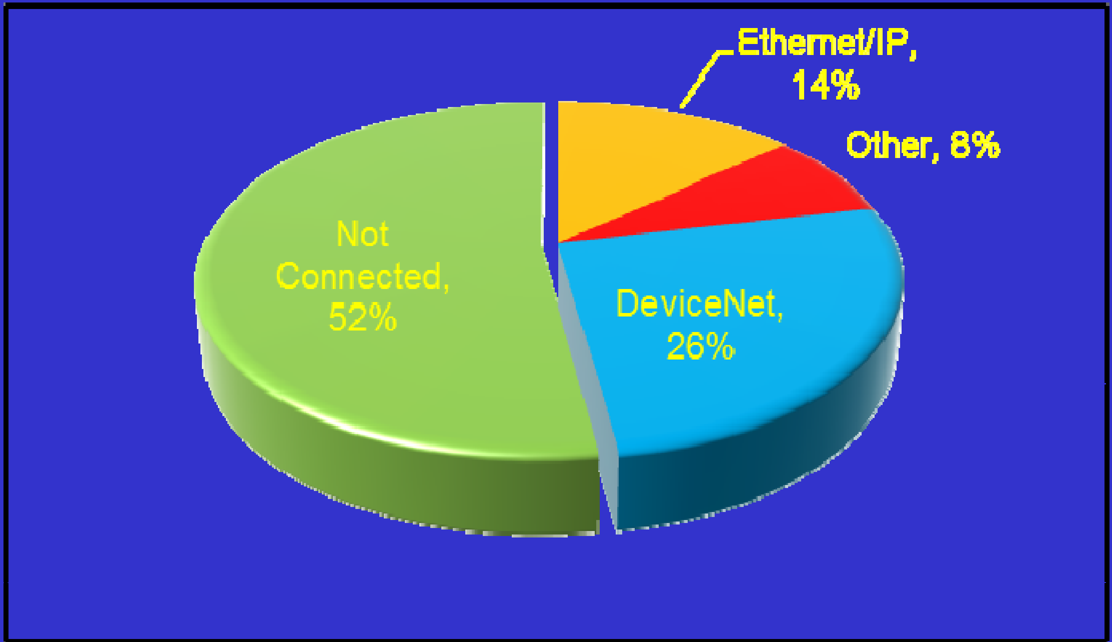
- More demand & extensive use of information
- Intelligence – predictive maintenance – drive and application
- Increased Connectivity
  - EtherNet
  - Remote Communications
    - Cloud Service
  - PLC integration – ease of use
    - Block Instructions
    - Automatic Device Configuration
  - Integrated motion

Ethernet

Percentage of MV MCCs that are connected to networks have increased from 30% to 48% in the last 3 years

Ethernet/IP is growing rapidly and displacing DeviceNet as the network of choice in MV MCCs

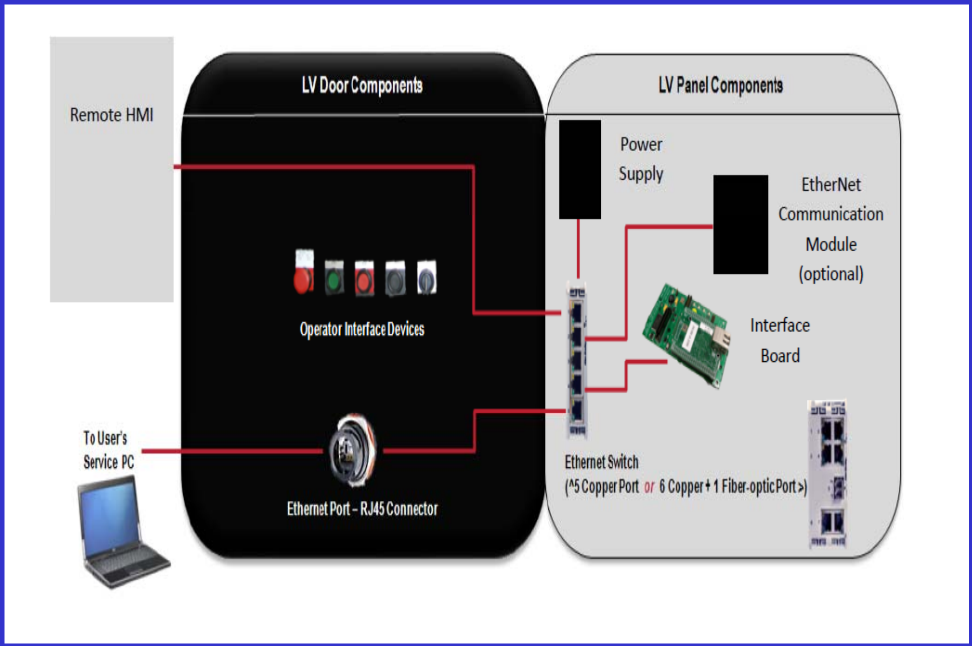
Connected MV MCCs, 2012



48% of MV MCCs are connected

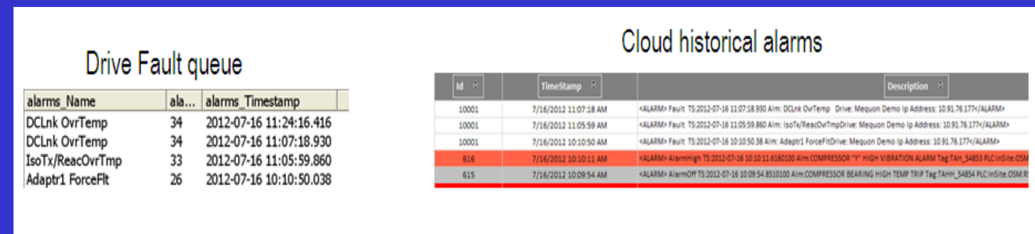
Remote HMI

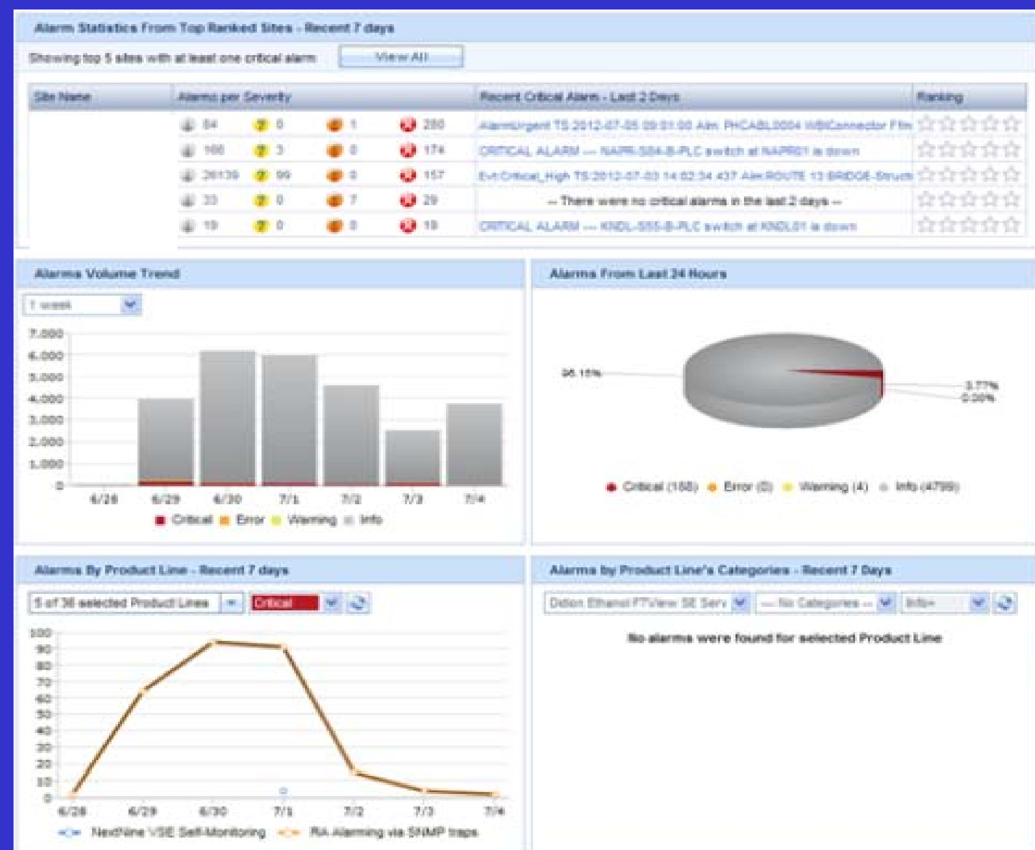
- Remote HMI or PC either in addition to or instead of an HMI on the drive
- Ease of use
  - Information can be obtained and parameters / firmware changed without the need to go to the equipment
  - Reduces need for work permits
- Increased safety
  - Minimize the need and time in front of electrical equipment

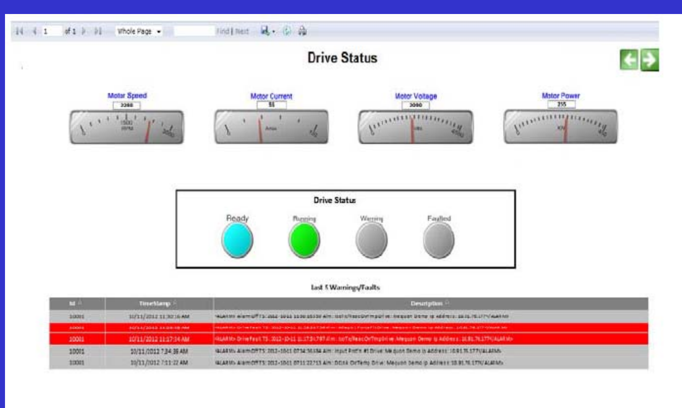


Remote Monitoring

- Internet & Cloud enabled
- Access external service expertise either on an as needed or continuous monitoring basis
- Data Storage
  - Maintain key information more securely
- Security
  - Read only to obtain information & troubleshoot



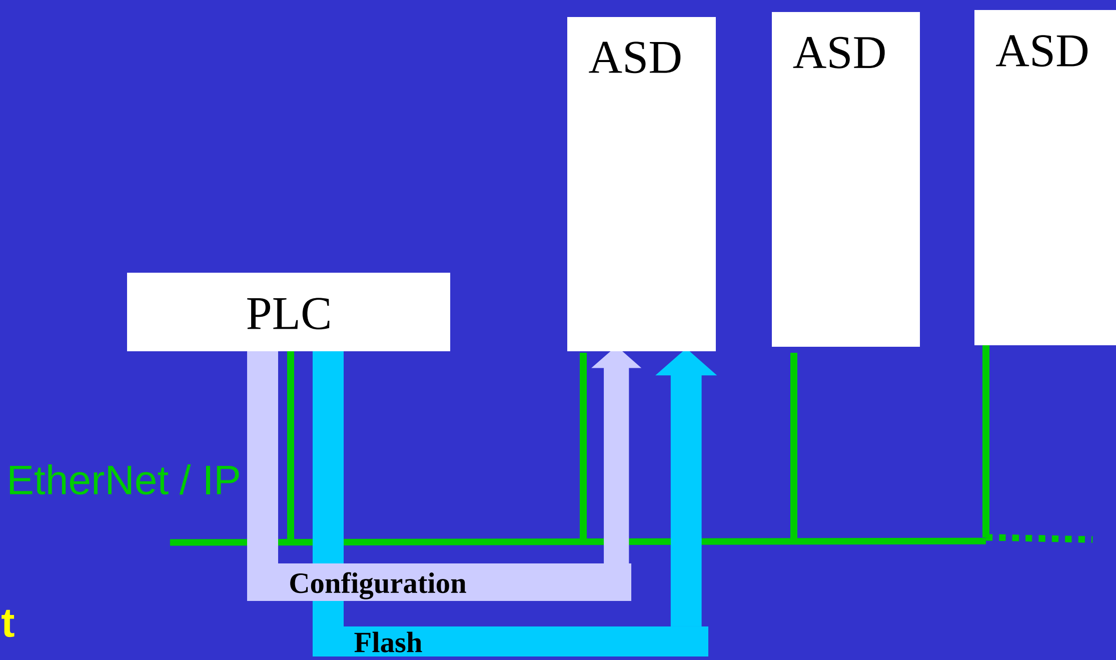




Integration with PLC

Instruction blocks for intelligent devices – ASDs, soft starters, etc.

- Automatic address assignment & tagging
- Ramp rates
- Ease of use – time savings / accuracy



Automatic Device Configuration

A PLC based feature that allows a user to configure their system to automatically download an intelligent device profile once established typically at time of replacement

Integrated Motion

- EtherNet Enabled
- Synchronized motion
- “Electronic drive shaft”
- Equivalent to a process sequencer
- Improve troubleshooting
- Time date stamp events
- Correlate activities on the system

Coordinates devices in a manner that’s similar to our own methods for coordinating meetings and events

- All members (devices) have clocks to compare time to an absolute base and scale
- A destination (position) is targeted for the event
- A time (timestamp) is set for when the event shall occur
- A message is sent to each member (device) to meet at a given place at the pre-determined time

Meeting
Conf Rm 2:00 pm

Integrated Motion

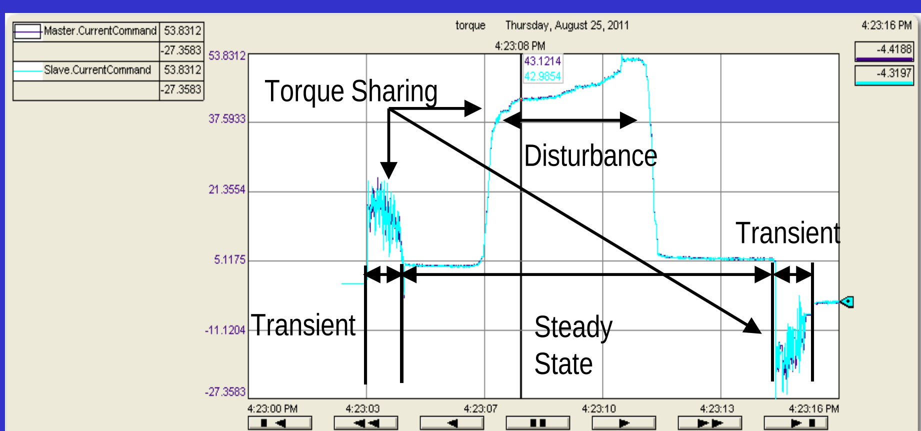
Machine / process synchronization

- Reduced equipment requirements
- Time stamped inputs
- Scheduled outputs
- Simplified code development

Tight coordination between ASDs / motors

Process component integration

High performance load sharing



Deviation is the command difference between the master and slave axes with 100 ns synchronization

Speed (rpm)	Deviation (deg)	Deviation (rev)
1000	0.0006	1.66667E-06
2000	0.0012	3.33333E-06
3000	0.0018	0.000005
4000	0.0024	6.66667E-06
5000	0.003	8.33333E-06
6000	0.0036	0.00001
7000	0.0042	1.16667E-05

Industry News & Trends

- Integral motor protection

- Safety
  - Arc Flash / Arc Mitigation
  - SIL ratings

- Permanent Magnet

Arc Mitigation - ASD

Under discussion in IEEE 1566 WG

Challenge is to determine the industry direction

- Arc Resistant
- Light Detection
- Other?

Functional Safety

- **Safety Integrity Level** (SIL) is defined as a relative level of risk-reduction provided by a safety function, or to specify a target level of risk reduction.
- Detailed requirements:
  - Safe Torque Off per IEC 61800-5-2
  - Desired targets:
    - SIL 3 per IEC 61508, IEC 62061
    - Cat. 3, PL=e per ISO 13849-1
- Where might you see this?
  - Material Handling / Conveyors
  - Pipelines
  - Hoists, winders
  - Grindings Mills
  - Underground coal mines

Increased use of Permanent Magnet Machines

PMM Control:

Permanent Magnet Synchronous Motor Control

- Preferred solution for low speed applications:
  - Marine
  - Wind, current, and tidal alternative energy markets

Cutaway view of PM motor in *wind turbine application*

Industry News & Trends

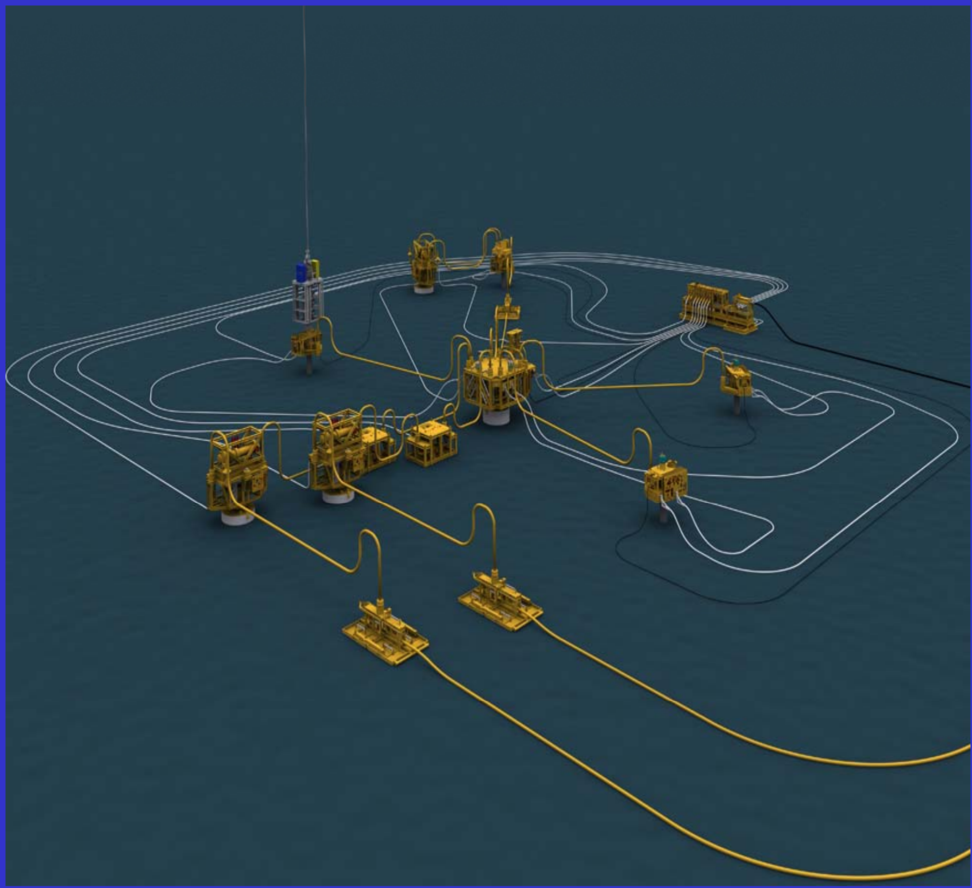
- Role of Operations & Maintenance in decision making process
- Decline of Subject Matter Expertise
- Increased demand for services & support
  - Application Support
  - Field Support
  - Training
  - Electronic manuals
  - Electronic knowledge and product notification

New Frontier - Sub-Sea Application

Current technology involves sea floor installation of boosting, separation and water injection systems along with transformers, power cables, connectors and penetrators needed to power these units

Typical applications

- Transfer & Injection Pumps
- Multi-Phase pumps
- Compressors
- Other processing equipment

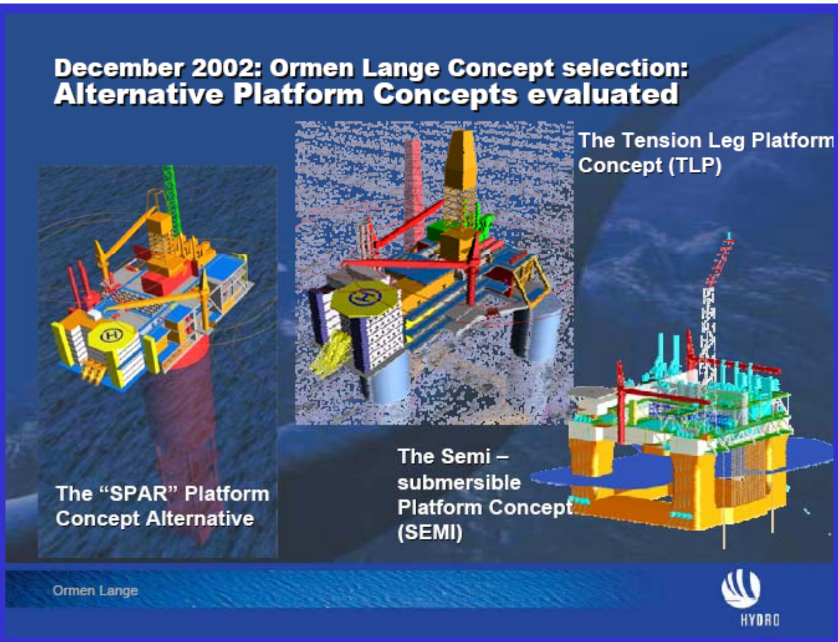


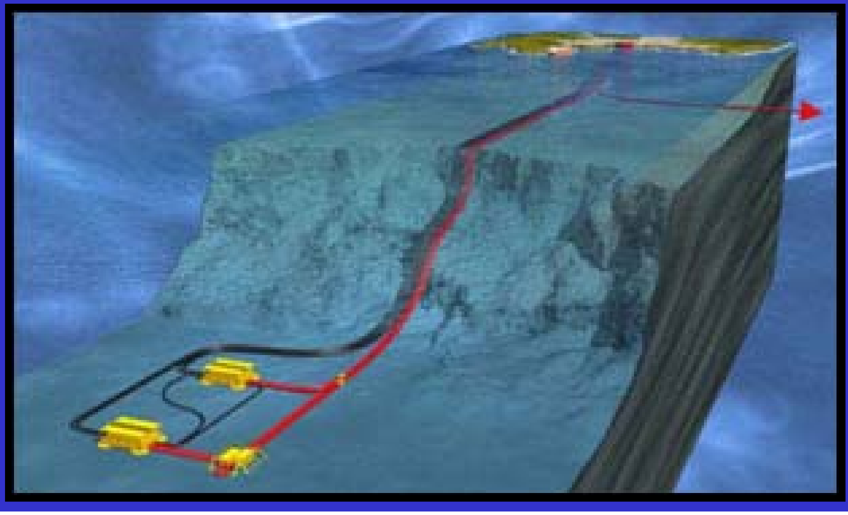
Environment

- Depth
  - 1500 to 4000 metres
- Temperature
  - -2 TO 4 degrees Celsius
- Pressure
  - 5689 psi / 392 bar – 4000 metres
  - 0.4335 psi per 1 foot water depth

Advantages of Sub-Sea Approach

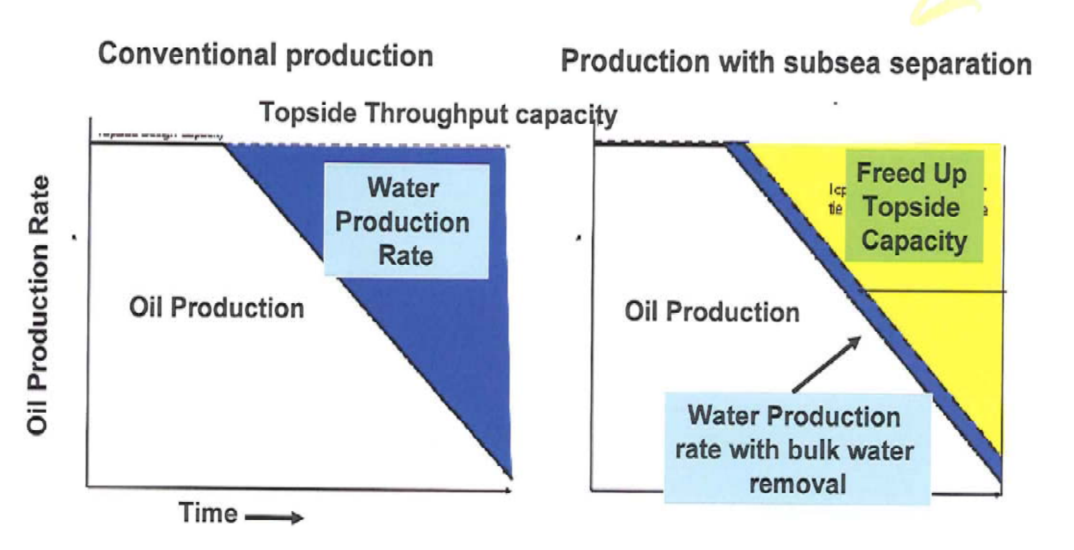
- Conventional Platform
  - $ 1 billion estimated cost
  - Manned facility
  - 25,000 Metric tons
  - Large support infrastructure
  - Icebreaking required in artic
- Subsea Application
  - Unmanned
  - ***20-25% increased recovery***
  - 30-40% lower capital cost



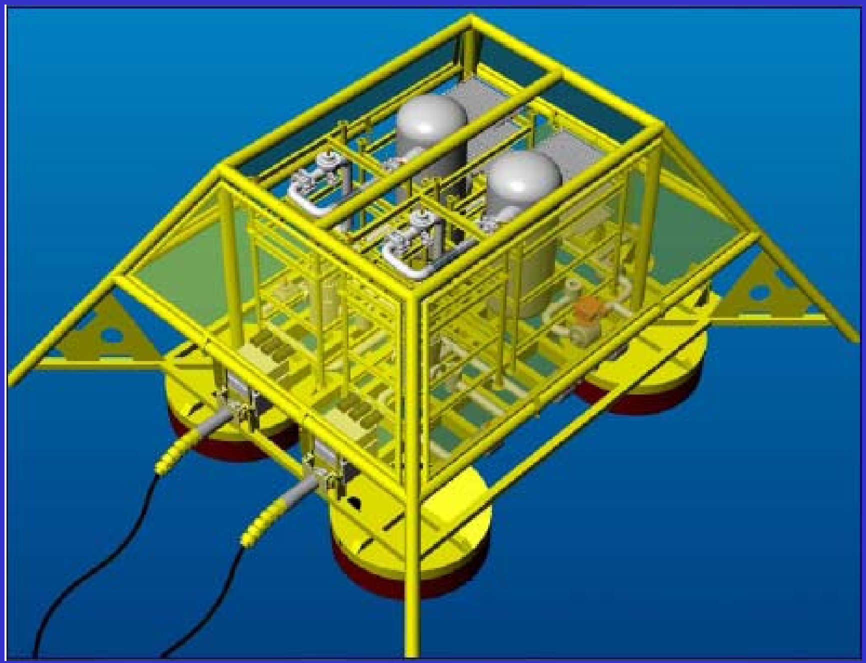


Advantages of Sub-Sea Approach

- Reduction in well head pressure
- Maintain the same flow
- Avoid the need to take oil and inherent water to the surface for processing.
- Water eliminated sub-sea can be immediately re-injected to the field with minimal energy required in this direction as well
- Reduced power requirement
- Reduced system design

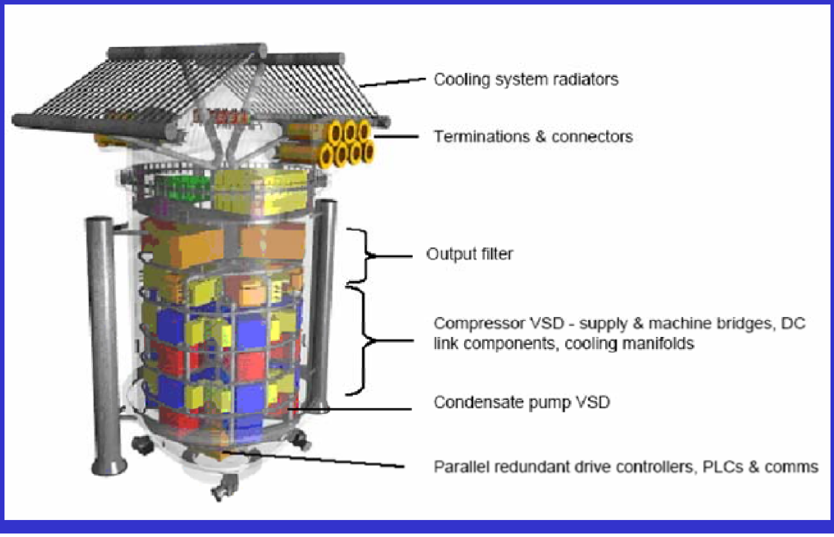


Designing for Subsea



- Packaging
  - Re-package of surface design
  - One atmosphere or oil compensated
  - Cost of and limitation of space and weight
- Limited accessibility
  - High cost & effort to access gear
- High availability is critical
  - Due to the expense and time required to access equipment, there must be increased focus on margins, reliability and testing
- Service schedule
  - Customers require / request > 5 years without the need to service

Adjustable Speed Drive Concepts



- Initial concept
- Last update is that unit has passed shallow water testing
- One atmosphere approach
- Thick enclosure – high cost & weight
- Initial feedback is that one atmosphere approach not practical
- Not expected to be a long term
- solution to subsea ASDs
- Oil compensated approach needed

Subsea Study Group

- ISO/FDIS 13628-6:2006(E) – Control
- IEEE Subsea Study group has been formed
- Development with dual-logo IEEE/IEC will be considered by the Study Group.
- Existing IEEE and other applicable industry and international standards will be reviewed

- Study Group Officers
  – Roy Jazowski – Teledyne - Chair
  – Stephen Lanier – ExxonMobil – Vice Chair
  – Min Zhou – Shell Projects - Secretary

IEEE Petroleum and Chemical Industry Committee

http://mentor.ieee.org/subsea-wg

IEEE Subsea Electrical Working Group

Expanding Applications list

MV Drives Increasing capabilities

- Expanding markets by improving performance, features & benefits
- Power Factor improvement and control, VAR compensation
- Comprehensive protection package for drive and motor
- Permanent Magnet motor control
- Process flexibility
- Communication capabilities
  - Variety of protocols
  - Integrated, transparent diagnostics automatically recording key variables
  - Upgraded interface capabilities, incorporating manuals, drawings and diagnostics
- System type drive integration capabilities

Summary

Numerous benefits of MV Drives

- Energy savings
- Reduced electrical and mechanical disturbances
- Enhanced process control
- Improved reliability

Future of MV Drives lies in

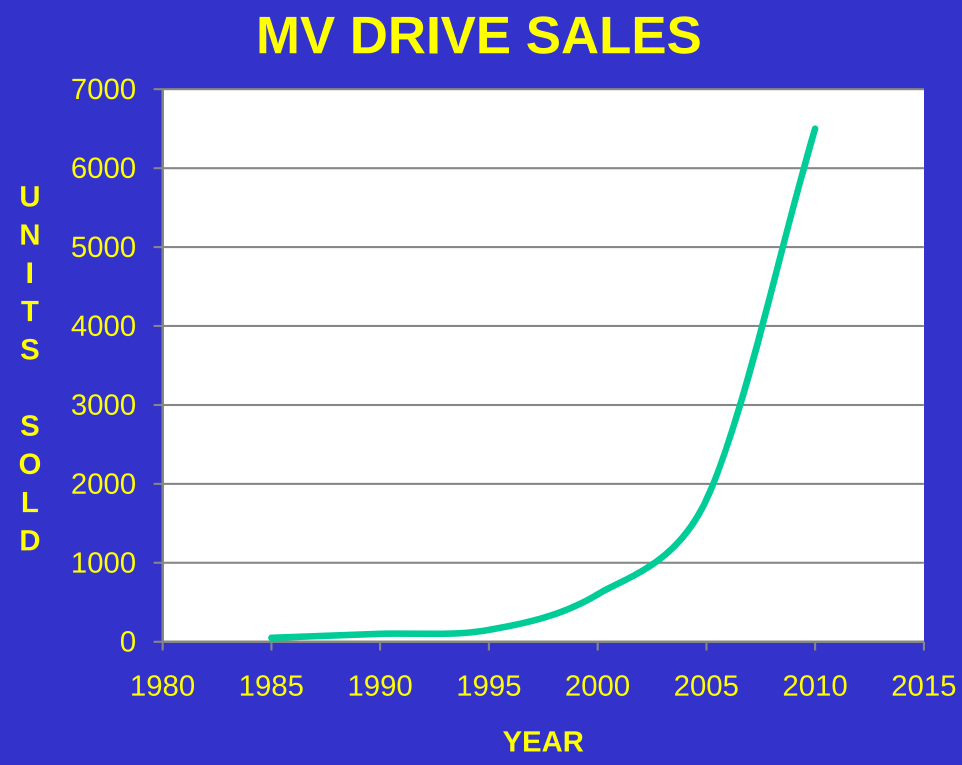
- Improving features and benefits
- Expanding drive use into more demanding applications
- Continued size and cost reductions
- High availabilty

ASD History

- ASDs have been used in process applications for some time – since 70's
  - Improved process control
  - Efficiency & energy savings
  - Allow starting on weak power systems within utility constraints
  - Eliminate mechanical components – valves, gearboxes, etc.
  - Reduce installation and maintenance costs
- Initially, as drives were new technology, the ASD was the project
- With more extensive usage, innovation in terms of ease of use and other factors have made this simpler so the focus becomes application and required performance
  - Efficiency, power factor, etc.

Large Adjustable Speed Drive Usage

- While drives have been in use since the 1970’s, usage has progressed nearly exponentially
- Currently a single manufacturer produces more drives in one year in one facility than the total demand in year 2000
- Northern Alberta represents perhaps the highest concentration in the world. Majority of drives are current source



Large Adjustable Speed Drive Usage

Reasons for increased usage

- Need to reduce energy costs
- Limited world wide electrical distribution
- Improve motor performance – starting, dynamic
- Industry acceptance
- Environmental factors – greenhouse gas emissions
- Technological improvements
  - Ease of design and use
  - Reduced footprint / ease of installation
  - ASD cost reductions - $$ per horsepower
  - Reliability
  - Proven technology

Need for a performance standard

- Baseline for a variety of drive topology choices + benefits
- Many technology options, fast changing
- Provides industry wide alignment of terminology and approach
- Useful for suppliers to monitor industry needs
- Need to define requirements and offering
- Ability to make effective comparisons

Need for a performance standard

Topology is discussed primarily as a means for technical personnel to understand performance

As can be seen, there are many variations in drive topologies

Important items for ASD users

- Availability – MTBF / MTTR
- Product life – 20 years
- Ease of use
- Maintenance
- Features
  - Regenerative braking
  - Communications / Connectivity

Need for a performance standard

- Consolidates intent / requirements of various other standards
    - IEC, NEMA
- Eliminate confusion
- Reduce the time needed to define an application
- Guiding direction for first time system designers
- Reference for more experienced users

IEEE 1566 Objectives

- Stand alone document
- Specify performance rather than design
- Provide the required data sheets
- Reduce confusion
- Reflect industry trends & needs
- Leverage on experience of numerous users
- Not all items can be achieved immediately

IEEE STD. 1566 STANDARD FOR PERFORMANCE OF ASD AC DRIVES RATED 375 KW AND LARGER

Standard applies to ASD applications – induction and synchronous AC machines

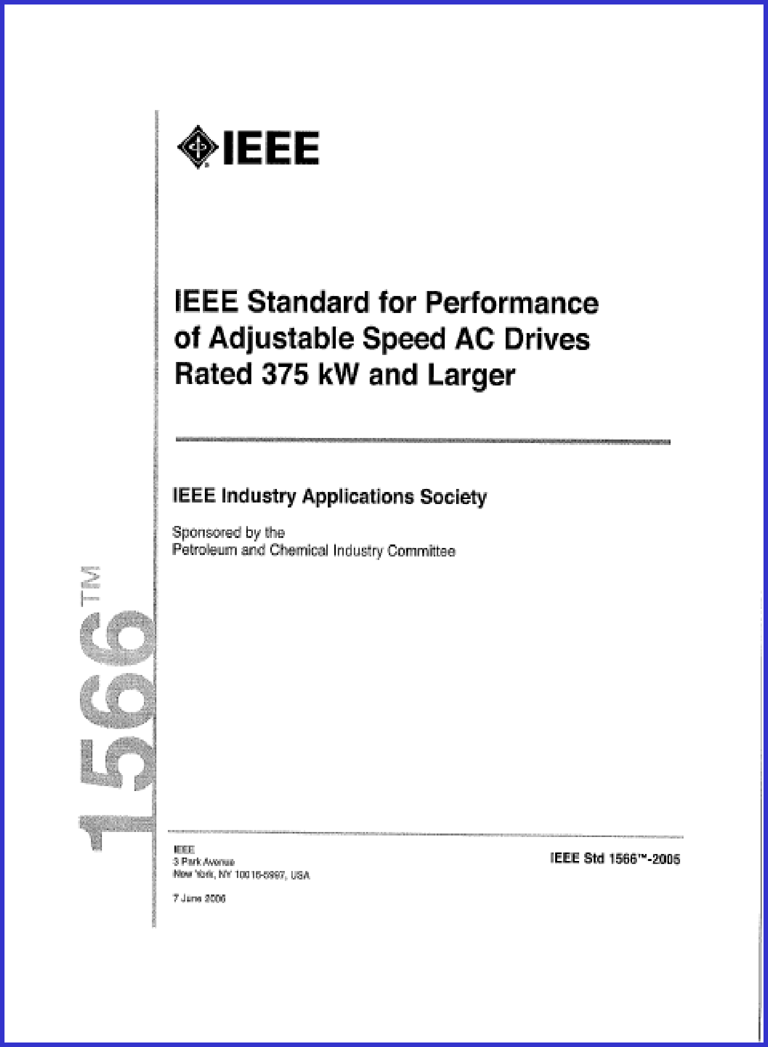
- > 375 kW (500 HP)

First release of the document

June 2006

Culmination of 6 years of work

Input provided and document written by IEEE members


IEEE

IEEE Standard for Performance of Adjustable Speed AC Drives Rated 375 kW and Larger

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee

1566™

IEEE
3 Park Avenue
New York, NY 10016-5997, USA

7 June 2006

IEEE Std 1566™-2005

What’s New in 2014 revision

- Enhanced Data Sheets
- Data Sheet Format – Excel
- Data Sheet Guide
- Adjustments to voltage sag & ride-through
- Introduction of arc flash values to data sheets
- Long Cables
- Marine
- Generator Supply

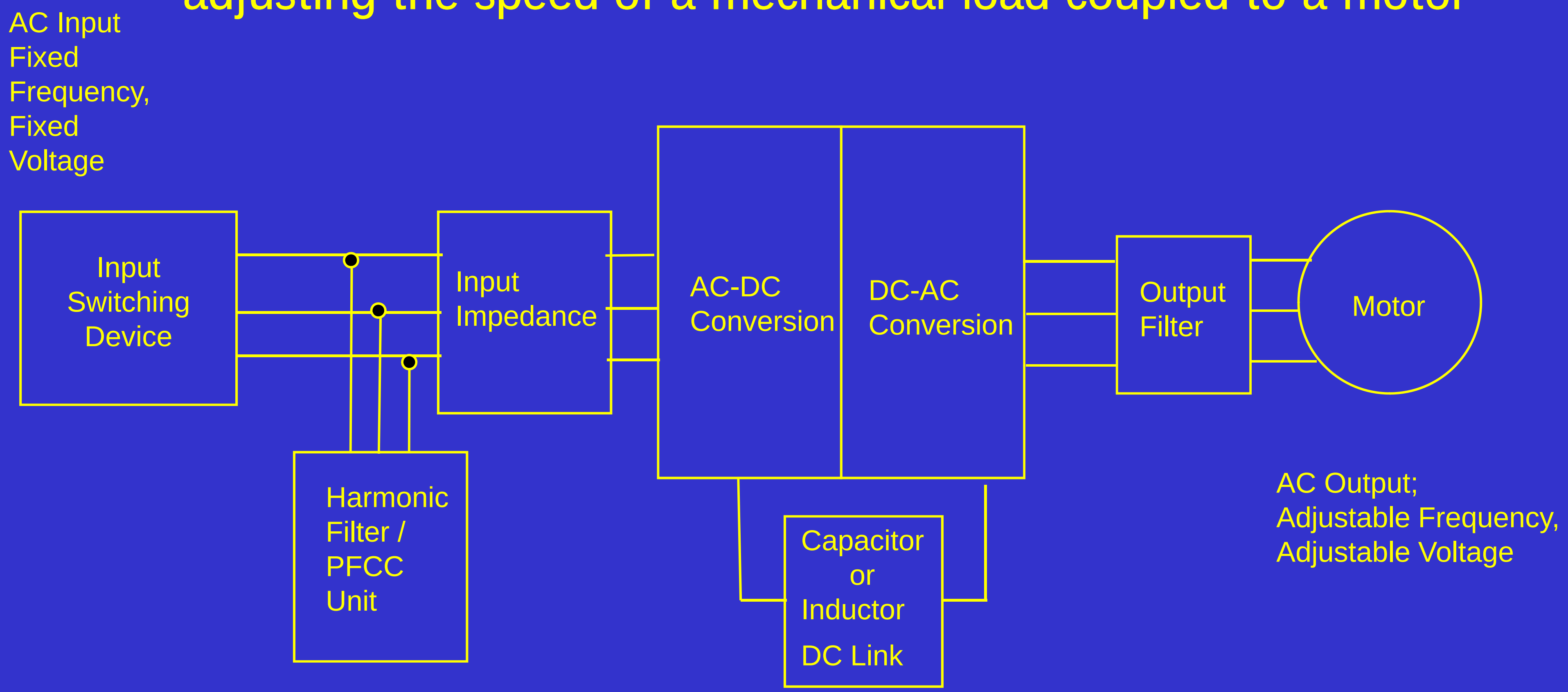
IEEE 1566 Scope

AC Adjustable Speed Drive System

- Safety
- Availability
- Enclosure
- Grounding
- Bonding
- Component ratings
- Load capability
- Ride-through
- Harmonics
- Controls
- Design Margin
- Cooling
- Bypass
- Switchgear
- Transformer/reactor
- Motor
- System coordination
- Testing
- Commissioning
- Spares and support
- Data Sheets
- Engineering Studies

Adjustable Speed Drive System

"An interconnected combination of equipment that provides a means of adjusting the speed of a mechanical load coupled to a motor"



Enclosure and Safety

- Drive shall not pose a risk of fire, electric shock, or injury
- Minimum IP21 enclosure
- Withstand all normal mechanical and environmental stresses due to handling and installation
- Prevent access to live parts
- Confine a bolted fault at the available short circuit energy
- Visible isolating means
- Suitable warning labels
- Capacitor discharge
- Arc Mitigation

Drive Topology

- Design requirements and performance rather than specific converter topology
- Power components conservatively rated
- Redundancy (N+1) is discussed as an option
- Replaceable components to be removable by no more than two people
- Isolation between power and control

Performance

- Accelerate / full output power with input voltages between 90% and 110% of nominal
- 110% motor full load current continuously – margin or contingency
- Optional variations, High Starting Torque?
- Short time overload capacity of extra 10%
  - 120%of motor FLC for 1 minute in every 10
- Will reduce the need for drive upgrades and give a more durable drive

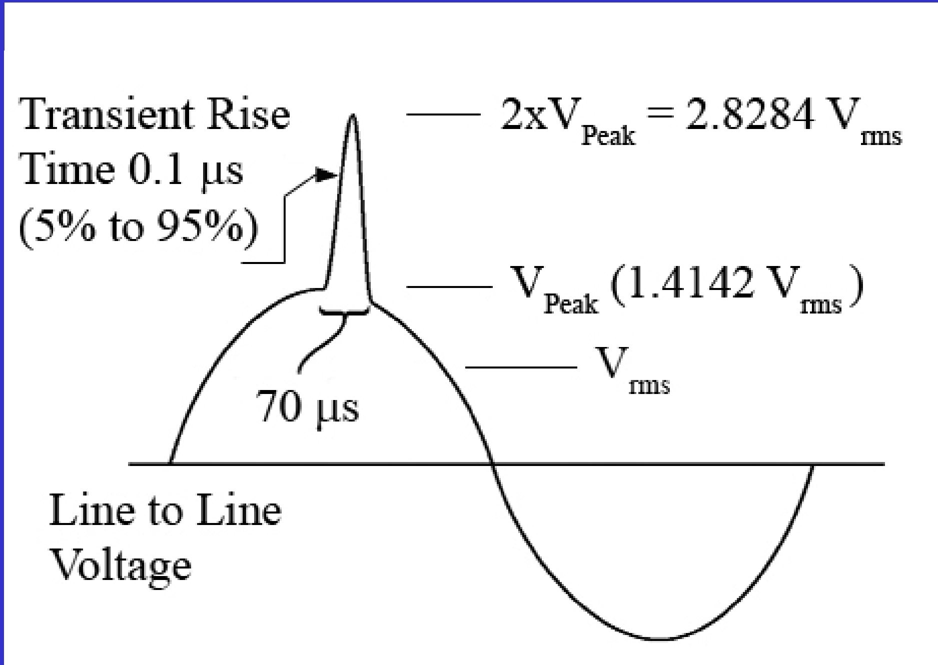
Input Tolerance

- Transient Voltages
  - Reliable operation with occasional input transients
- Flying Restart after 100% power loss of at least two seconds
- Voltage Sags

Voltage Transient

ASD System shall operate reliably and without interruption when

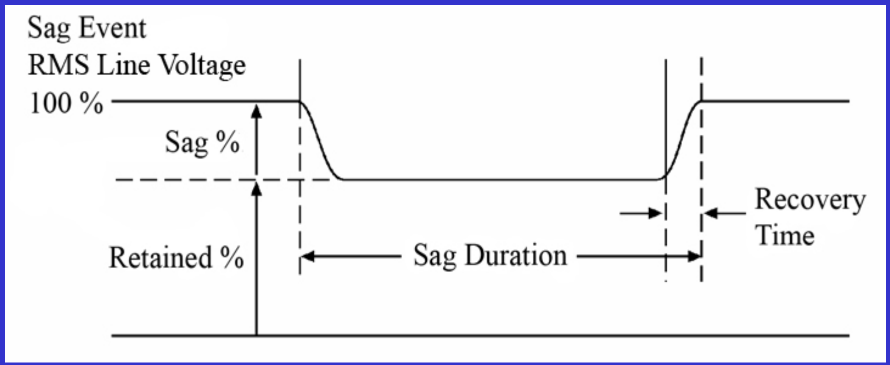
- Input power supply over-voltage transients of 2.8 times the nominal rms
- Rise time of 0.1 µs
- Base width of 70 µs



Voltage Sag

Maintain motor control during three-phase input power supply loss

Voltage sag to 65% of nominal on one or more phases for a duration of 500 ms



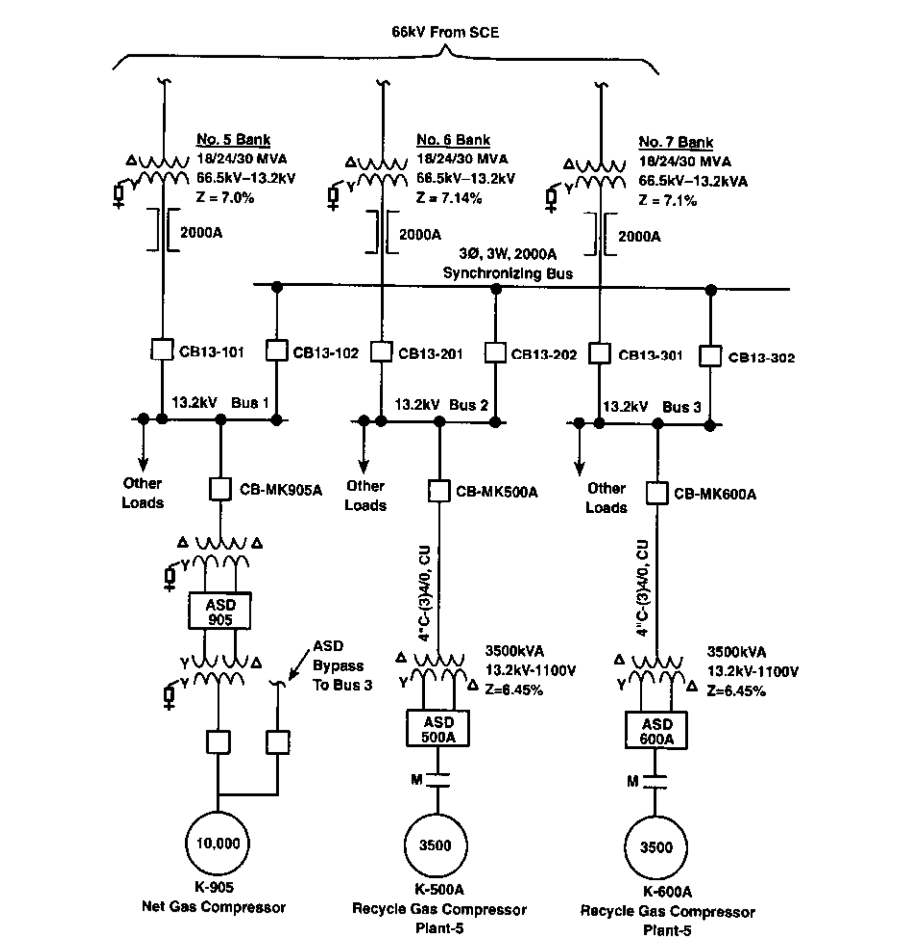
Harmonics and noise immunity

IEEE Std 519 is used as the default harmonic generation standard

Items to be specified by user

- Telephone interference level
- Point of Common Coupling
- Extra requirements

Acceptable levels of Electromagnetic Interference and Radio Frequency Interference are also specified



Control

- Various control and communication options
- Defines requirements for local/ remote operation
- Alarm and fault diagnostics, first out report sequence
- Non volatile alarm and shutdown data
- Trending and troubleshooting requirements
- All data available on digital link
- Include all required software and interface devices
- Alarm and shutdown indications by both NC and NO contacts wired to individual terminals
- Skip frequencies
- Loss of speed reference signal - user selectable action
  - Maintain speed
  - Stop
  - Go to predefined speed level

Bypass Operation

- Transfer motor between drive and utility, and back again
- Useful for starting duty (speed control not required) or approach to operational redundancy
- Must consider whether maintenance / repair can be performed on drive
- Multiple motors, one drive
- Various options available

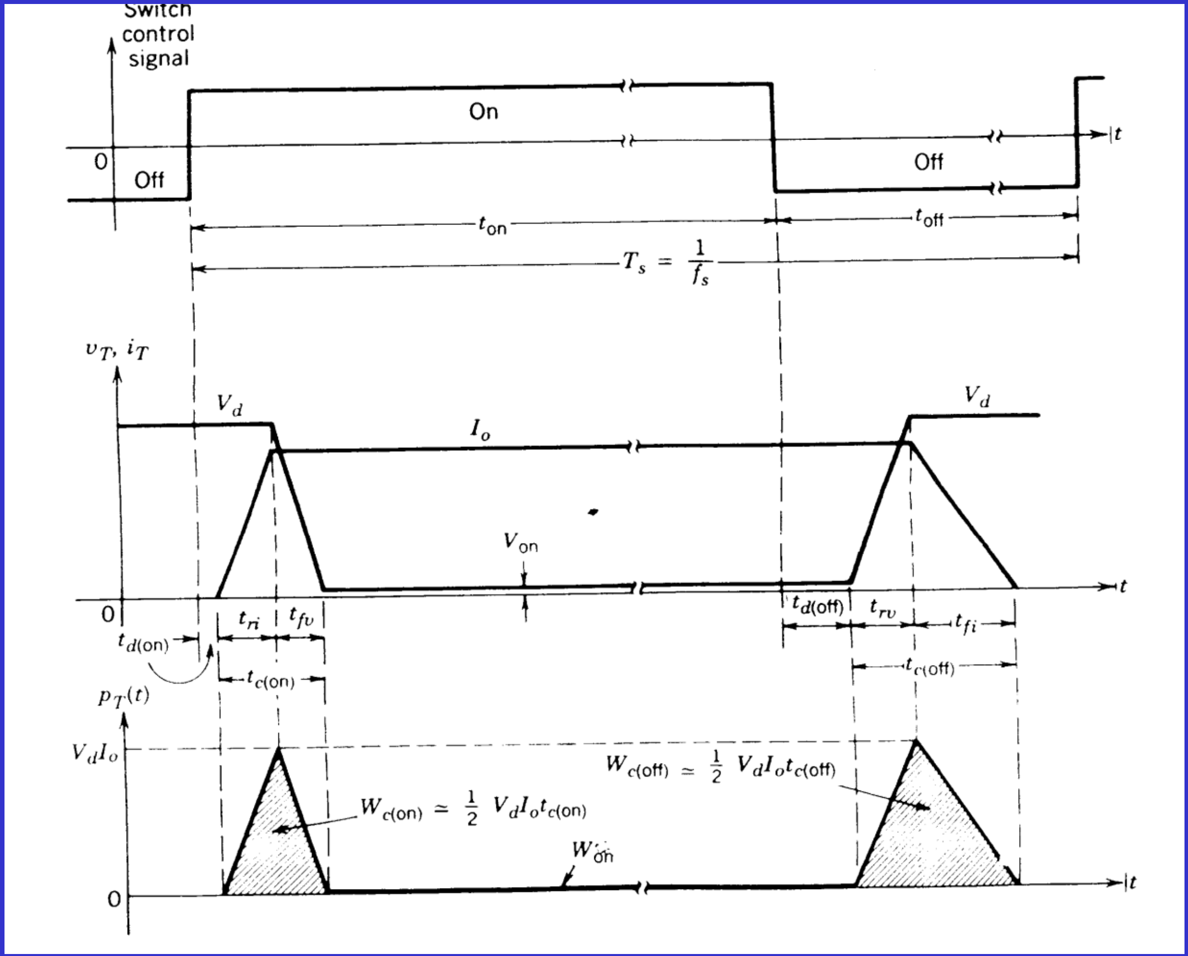
Input impedance
Transformer / reactor

- Coordinated Component of the System
- ANSI standards
- Harmonic requirements
- Isolation, Phase shift
- Reduce Fault Levels
- Indoor or Outdoor

Cooling

- Air or Liquid Cooling
- Redundancy - optional on fans, required on pumps
- Single failure alarms; Second failure shuts down
- Alarms and shutdowns for heat sink over-temperature.
- Fans / pumps automatically switch a minimum of every 30 days without requiring a shutdown
- L10 bearing life of at least 50 000 hours.

DEVICE LOSSES



Switchgear & starters

Should be included in ASD supplier scope

Mechanical and electrical interlocking to be defined by ASD supplier if not in scope

Applicable ANSI/IEEE standards are referenced

Motor

- API 541 (Induction) and API 546 (Synchronous)
- Diamond Bullets in API
- Effect of harmonics, voltage stresses – long motor life
- NEMA MG-1 Sections 30 and 31 has useful data

Motor

- Consider effect of reduced cooling at lower operating speeds
- Synchronous machines field excitation
- Hazardous Locations

Documentation

Drawings must conform to local requirements

- Symbols, etc.

Typical approval process described

Final documentation

- Storage and maintenance instructions
- Operating instructions
- Project drawings
- Complete list of renewal parts
- Recommended spare parts
- Test reports
- System studies

Availability, Service and Support

System design shall provide

- 20 year service life
- 5 year continuous operation
  - L10 life on cooling fan of 5 years +
  - Identify any redundancy requirements
- 20 year service life plan should be available
  - Spare parts – identify components requiring replacement over 20 years
  - Training
  - Service support
  - Provide expected MTBF and MTTR

There may be a point where replacement with new technology is more practical

HAZARDOUS LOCATIONS & MOTORS

- DRIVES INCREASE HEAT GENERATION SLIGHTLY (HARMONICS ON ROTOR)
- HEAT DISSIPATION FROM SHAFT MOUNTED FANS IS REDUCED AT LOWER SPEEDS
- CAN GIVE SLIGHT ROTOR TEMPERATURE INCREASE
- AVAILABLE DATA SHOWS SELDOM A CONCERN
- IEEE 1349 HAS EXTRA DATA

HAZARDOUS LOCATIONS AND VOLTAGES

- ALL DRIVES GENERATE “COMMON MODE VOLTAGE” (CMV) TO SOME EXTENT
- NEUTRAL POINT IS DISPLACED FROM ZERO
- MAGNITUDE DEPENDS ON DRIVE TOPOLOGY
- STATOR WINDING VOLTAGES ARE DISPLACED FROM ZERO
- THE ROTOR BUILDS UP A CHARGE TYPICALLY ABOUT 10% OF STATOR CMV (DEPENDS ON MOTOR CONFIGURATION)
- ENERGY STORED ON ROTOR

ROTOR ENERGY

ROTOR CAPACITANCE TO FRAME C

ROTOR VOLTAGE V

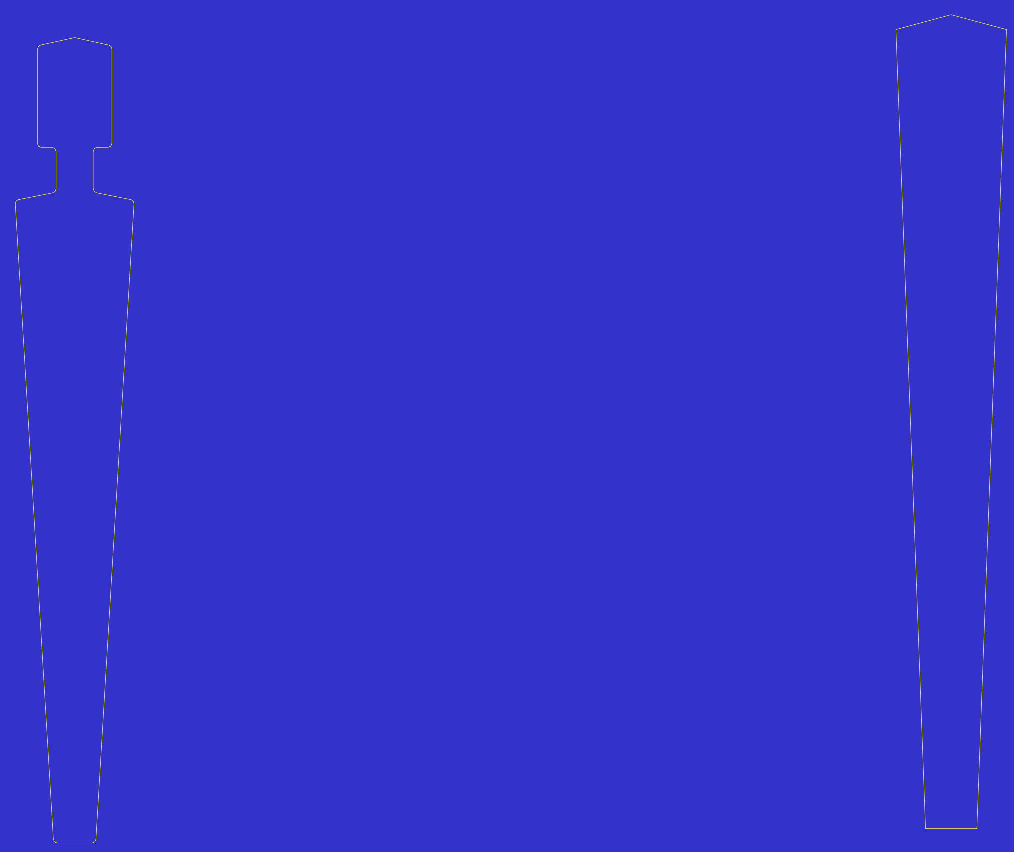
$$\text{ENERGY} = \tfrac{1}{2} CV^2$$

CAN IT IGNITE EXPLOSIVE MIXTURES?

How To Reduce Rotor Rise

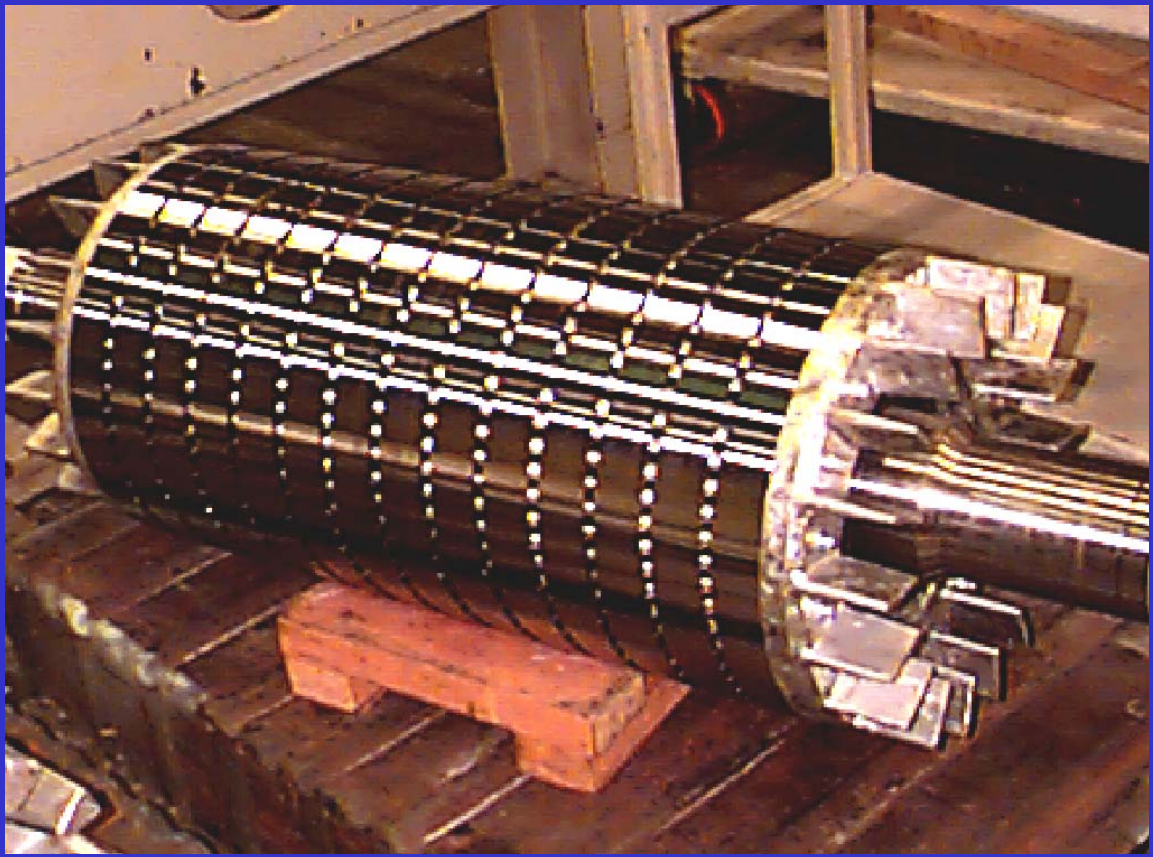
- Copper Bars Rather Than Aluminum
- "Open" Construction
- Higher Number Of Poles
- Optimize Rotor Bar Shape For Inverter
- Ducted Rotor
- Low Slip

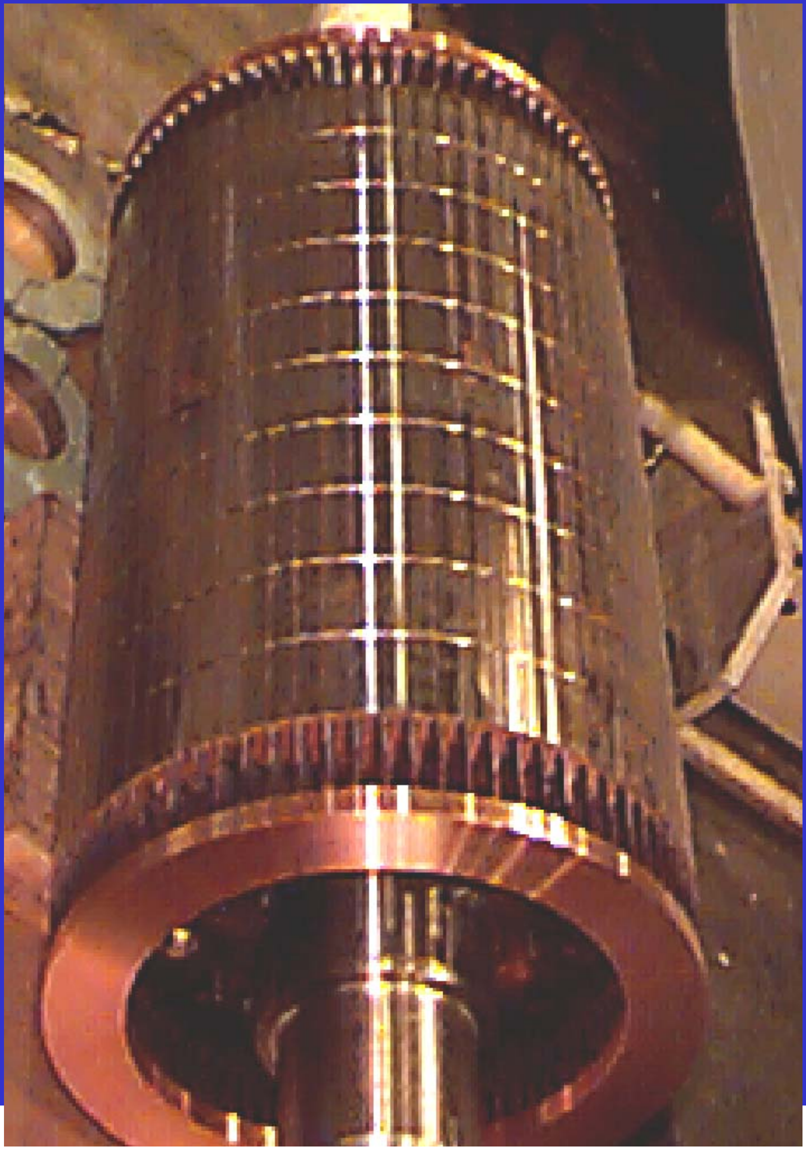
Reducing Rotor Temperatures Slot Shape for Inverter Power



LINE START INVERTER OPTIMIZED

Ducted / Copper Bar rotor





Ignition Temperatures

Methane	537°C	Gasoline	280°C
Ethane	472°C	H_2S	260°C
Propane	432°C	Pentane	260°C
Hydrogen	429°C	Hexane	223°C
Acetylene	305°C	Octane	206°C
Butane	287°C	Heptane	204°C

Common Mode Voltages

- CMV Is a Natural Consequence of Inverter Switching
- All Inverter Topologies Produce CMV To Some Extent
- May Be As High As 4400 Volts (Peak Neutral to Ground on 4160 V_{rms} System)
- "CMV Mitigation" Can Be Employed by a Variety of Means

CALCULATION OF ELECTROSTATIC ENERGY STORED IN ROTOR

			NOTES
ROTOR TO FRAME CAPACITANCE:			
Rotor Length:	1.00	meters	1.0 meter = 39.37 in
Rotor Diameter:	1.00	meters	
Air Gap:	0.01	meters	
CAPACITANCE:	2.7789E-09	Farad	
	0.0027789	Microfarad	
BEARING CAPACITANCES:			
Babbit Length	0.0635	meters	
Journal Diameter	0.1524	meters	
Bearing Clearance	0.0001524	meters	
CAPACITANCE:	7.05841E-09	Farad per bearing	Takes Oil as 4.0 Dielectric Constant (Typically 2.5)
TOTAL CAPACITANCE:	1.68957E-08	Farad	
	0.016895712	Microfarad	
PEAK MEASURED SHAFT VOLTAGE:	5	Volt	
STORED ENERGY	2.11196E-07	Joules	
	0.2111964	Microjoules	
COMMON MIEs			
Butane	250	Microjoules	
Methane	280		
Pentane	280		
Ethane	240		
Propane	250		
Acetylene	17		
Hydrogen	18		

Testing – Factory & Combined

- Thorough Factory Testing is Vital
- Burn in Devices
- Hipot
- Full Current and Voltage Heat Run
- Test all Auxiliaries
- Test Motor Separately, and on Drive where Practical

Annexes

Annex A - Purchaser Data Sheet

Annex B - Manufacturer Data Sheet

Annex C - Data Sheet Guide

Annex D & E - Informative

- Engineering Studies - D
- Bibliography - E

Essential that A & B information must be exchanged during the course of a project

IEEE Std 1566-2005
IEEE Standard for Performance of Adjustable Speed AC Drives Rated 375 kW and Larger

Annex A

(normative)

Technical data sheet (to be completed by the purchaser)

Project Reference: Spec. Reference: ____________________ **Date:**

System of units: ☐ SI ☐ SI plus U.S. standard

Power System One-Line Diagram Provided: ☐ Yes ☐ No

Details: ____________________

Supply system voltage:

☐ 2 400 V ☐ 3 300 V ☐ 4 160 V ☐ 6 900 V ☐ 13 800 V ☐ Other: V +/-_ _%

Short circuit level: MVA **Line frequency:** ☐ 60 Hz ☐ 50 Hz

Point of common coupling (PCC) ____ Required telephone influence (I.T) at PCC

Average demand current (I_L) ____ Other harmonic requirements: ____________

Ground fault detection provided in upstream switchgear: ☐ Yes ☐ No

ASD Auxiliary Three-Phase Power

60 Hz: ☐ 208 V ☐ 480 V ☐ 575 V ☐ Other 50 Hz: ☐ 400 V ☐ Other

Control Power: ☐ From input ☐ UPS ☐ Battery ☐ Voltage ________

UPS or battery supplied by: ☐ Vendor ☐ Purchaser

Load/Application Requirements

Type of load: ☐ Fan ☐ Pump ☐ Other ____________________

Torque profile: ☐ Variable ☐ Constant ☐ Other ____________________

Gearbox ratio: ☐ ________ to ________ ☐ None

Motor speed range: ________ r/min to ________ r/min

Max load power ________ kW at ________ r/min

Load torque/Speed curve provided ☐ Ref: ____________________

Design Standards

☐ UL 347A ☐ IEC 61800-5-1 ☐ Other ____________________

HOW TO ORDER A DRIVE

- ANALYZE THE REQUIREMENTS
- DECIDE WHAT IS NEEDED
- USE A STANDARD (IEEE 1566)
- COMPLETE THE PURCHASER DATA SHEETS
- REVIEW THE VENDOR RESPONSES
- WORK OUT DETAILS
- MAINTAIN COMMUNICATIONS
- TEST THOROUGHLY
- INSTALL AND START UP

Ask for What You Need

Use a Specification

IEEE 1566

Complete the Data Sheet!

Check That You Get What You Need

- Review Vendor’s Data Sheet
- Ask Questions
- Test at Factory
- Test at Site

Training and Startup

Train the Owner's People

Do a Thorough Startup

IEEE 1566 DATA SHEETS

PURCHASER DATA SHEETS

VENDOR DATA SHEETS

DATA SHEET GUIDE

IEEE | Issued for use by: | Sheet 1 of 3 | DOCUMENT NO. 0 | Rev. 0

IEEE 1566 - MEDIUM VOLTAGE ADJUSTABLE SPEED DRIVES ELECTRICAL DATA SHEET

JOB NO. 0 ITEM / TAG NO 0

PURCHASE ORDER NO 0

REQ. / SPEC. NO. 0

REVISION NO. 0 DATE 6/15/2013 BY

Applicable To: ◯ Proposal ◯ Purchase ◯ As built

NOTE: ◯ DATA SHEET STATUS ◯ INDICATES INFO. TO BE COMPLETED BY PURCH. ☐ TO BE COMPLETED BY MANUFACTURER

Annex B - To be completed by the manufacturer

General Information

Vendor ____ Manufacturing Locatio ____

Model Numbe ____

ASD rating (5.3):

kW: ____ Input Voltag ____ V Output Voltag ____ V

Arc flash incident energy based on maximum and minimum MVA level provided at annex A:

Drive input cabinet ____ cal/cm²

Power electronic cabine ____ cal/cm²

Drive Output Cabine ____ cal/cm²

Supply system voltage (6.1):

☐ 2400V ☐ 3300V ☐ 4160V ☐ 6600 V ☐ 13800 V

Other ____ V ± ____ %

Line Frequency: ☐ 60Hz ☐ 50Hz

ASD Auxiliary Three-Phase Power (6.1):

60Hz: ☐ 208V ☐ 480V ☐ 600V ☐ Other ____ V

50Hz: ☐ 400V ☐ Other ____ V

Capacity Required Contr ____ kVA

Capacity Required Fan(s ____ kVA

Capacity Required Pump(s ____ kVA

ASD Auxiliary Devices requiring motor starter (6 ☐ Yes ☐ No

If Yes, to be powered by owner's MC ☐ Yes ☐ No

Capacity (6.3):

Continuous capacity at 40 °C ambier ____ kW

1 min overload capacity at 40 °C ambi ____ A every ____ min

Maximum continuous volta ____ kV

Acoustic Noise Level (6.17 ____ dB(A)

ASD Supply Voltage Ridethrough (6.18)

Ride-througl ____ cycles

Input surge protection typ ____

Reliability (1.3, 13.6):

ASD MTBF:

ASD MTTR:

ASD is suitable for a minimum of five years of continuous operation (1.3)

☐ Yes ☐ No

Other ____

Switching device replacement t ____ minutes

Availability ____ %

Enclosure (4.2.1):

☐ Indoor IP21 ☐ Other. Specify ____

Gland Plate Location

Incoming Power Cable ☐ Top ☐ Bottom

Size ____ Number per Phase ____

Motor Cables ☐ Top ☐ Bottom

Size ____ Number per Phase ____

Control Cables ☐ Top ☐ Bottom

Finish: ☐ Manufacturing Std. ☐ As Specified

☐ Outside Colour: ____

☐ Inside Colour ____

Rear access required: ☐ Yes ☐ No

Drive weight ____ kg

Drive dimensions (WxHxD) ____ mm

Rectifier (5.4):

Pulse number ☐ 6 ☐ 12 ☐ 18 ☐ 24 ☐ 30

☐ Other ____

☐ Active front end (PWM rectifier)

Power semiconductor switching device

☐ SCR ☐ SGCT ☐ Diode ☐ IGBT ☐ Other ____

Peak inverse voltage rati ____ V

Average current ratin ____ A

Total # of rectifier switching devic ____

Cooling: ☐ Single Sided ☐ Double Sided

Total # of rectifier power fus ____

Rectifier power fuse rating ____ V ____ A

Precharge circuit?: ☐ Yes ☐ No ☐ Not Applicable

DC Link Circuit (5.5):

For inductor

Specify winding materia ____

☐ Air-core ☐ Iron-core

DC Link Inductor:

☐ Integral to ASD ☐ External to ASD ☐ Non-saturable

☐ Split dual winding type ☐ Other ____

DC link inductor replacement frequency (5 ____ years

Total # of dc bus capacitor ____

DC bus capacitor replacement freque ____ years

Inverter (5.6):

Power semiconductor switching device

☐ SCR ☐ SGCT ☐ Diode ☐ IGBT ☐ Other ____

Peak inverse voltage ratin ____ V

Controllable on-state curre ____ A

Total # of inverter switching devic ____

Cooling: ☐ Single Sided ☐ Double Sided

IEEE | Issued for use by: | Sheet 1 of 3 | DOCUMENT NO. | Rev. 0

IEEE 1566 - MEDIUM VOLTAGE ADJUSTABLE SPEED DRIVES ELECTRICAL DATA SHEET

JOB NO. ITEM / TAG NO.

PURCHASE ORDER NO.

REQ. / SPEC. NO.

REVISION NO. DATE 6/15/2013 BY

1 FOR/USER ______ EQUIPMENT ______

2 SITE/LOCATION ______ MANUFACTURER ______

3 REFERENCE SLD ______ SUPPLIER PROJECT NO. ______

4 Applicable To: ◎ Proposal ◎ Purchase ◎ As built

5 NOTE: ◎ DATA SHEET STATUS ○ INDICATES INFO. TO BE COMPLETED BY PURCH. □ TO BE COMPLETED BY MANUFACTURER

Annex A - To be completed by the purchaser

6 **System of Units:** ○ SI ○ SI plus US standard

7

8 **Supply System Voltage (6.1, 6.6):**

9 ○ 2400V ○ 3300V ○ 4160V ○ 6600V ○ 13800V

10 Other: ______ V ± ______ %

11 Short Circuit Level (Max) ______ MVA at PCC ______ at drive

12 Line Frequency: ○ 60Hz ○ 50Hz

13 Short Circuit Level (Min): ______ MVA at PCC ______ at drive

14 Line Frequency: ○ 60Hz ○ 50Hz

15 Short Circuit Level at Drive Input for Arc Flash Energy Calculations:

16 ______ Maximum MVA ______ Minimum MVA Duration: ______ ms

17

18 **ASD Auxiliary Three-Phase Power (6.1):**

19 60Hz: ○ 208V ○ 480V ○ 600V ○ Other: ______ V

Harmonics (6.2, 6.15):

Impedance versus frequency data supplied at PCC? ○ Yes ○ No

Point of common coupling (PCC ______ Voltage at PCC: ______ V

Required telephone influence (I.T) at PCC ______

Average Demand Current (I_L) ______

Other harmonic requirements ______

Harmonic Compliance to IEEE 519: ○ Yes ○ No

Harmonic Compliance to IEC 61000-3-6: ○ Yes ○ No

If 'No' to both of the above, state voltage THD requirement at PC ______

System Grounding (6.5):

System Ground method: ○ Solid ○ Resistance at: ______ A

○ Other: ______

Ground fault detection provided in upstream switchgear ○ Yes ○ No

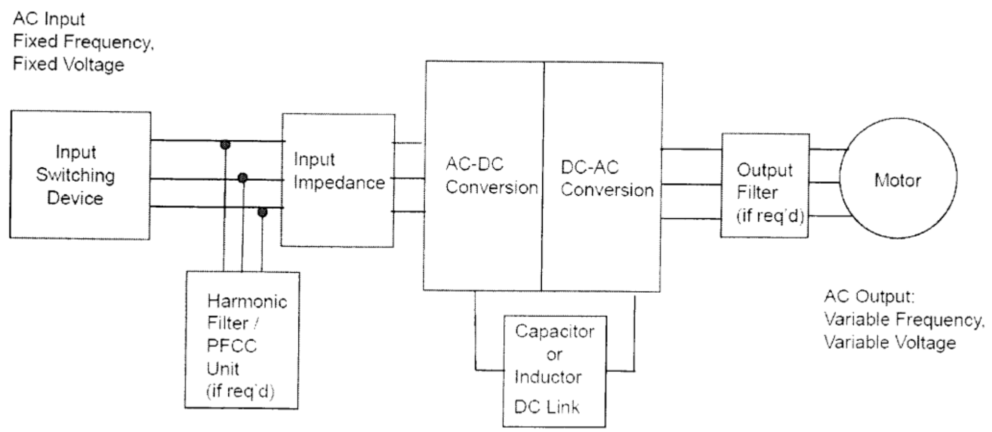
Annex C

(informative)

Technical Data Sheet Guide

This guide is designed to assist purchasers in specifying large adjustable speed drives for process applications. It does not cover all situations and should not be followed blindly. Corporate or local requirements may supersede some of the guidance listed here.

General: The system covered by this standard and data sheet comprises the equipment shown in the block diagram below. Not all the components shown below are relevant in each case, and some auxiliary devices such as fans and cooling water pumps are not shown.



Project Reference, Date: The data sheet may go through a number of revisions as project requirements change and vendor discussions indicate different requirements may be better for the purpose. Update the Reference and the Date as the sheets are revised.

Reference SLD: The vendor needs to know as much as possible about the power system feeding the ASD as this will affect the drive's performance. Early in a project, details of the power system are not always finalized, but the vendor should be given as much information as possible so that they can make an accurate proposal. As well as the SLD, supply any extra details that may be available, such as information on other loads on the system.

System of units: The standard permits either the SI (meters, kilograms, kilowatts etc.) system of units to be used alone, or the SI system plus the U.S. standard (inches, pounds, horsepower etc.) system. The selection is usually based on the system in use at the location.

Supply System Voltage: Some common bus voltages are listed here, but other voltages may be listed. Note that the expected normal variation in supply voltage should also be listed as the drive performance is affected by the level of input voltage, for example supplying full power at a

IEEE 1566 DATA SHEETS

VENDOR DATA SHEET

REVIEW THIS!

DATA SHEETS

ESSENTIAL FOR GETTING WHAT YOU NEED WITHOUT CONFUSION

COMMUNICATION!

TEST THOROUGHLY

- COMPLETE FACTORY TESTS
- SOLVE PROBLEMS IN THE FACTORY RATHER THAN ON SITE
- LOAD TEST
- CONTROL TESTS
- AUXILIARIES
- THOROUGH STARTUP
- TRAIN PEOPLE
- MAINTAIN PROPERLY

Summary

- Adjustable Speed Drives have become common place
- Increased use is due to the need for energy savings and other benefits which these controllers bring to all industries and a wide variety of applications
- Numerous drive choices currently in the marketplace
- IEEE 1566 has been created to assist users in specifying equipment on the basis of performance
- Recommend that you become familiar with this standard
- Standard must use the data sheets
- IEEE 1566 is a living document which is reviewed and updated regularly
  - Must be maintained by users through IEEE
  - Get involved

THANK YOU