An Overview of Medium Voltage AC Adjustable Speed Drives and IEEE Std. 1566 – Standard for Performance of Adjustable Speed AC Drives Rated 375 kW and Larger

Richard Paes
Special Applications Manager
Medium Voltage Business
Rockwell Automation

IEEE Southern Alberta Section
PES/IAS Joint Chapter Technical Seminar

Upcoming IEEE IAS Events

January 2011
Sheraton
Toronto, Ontario, Canada

http://www.ewh.ieee.org/cmte/ias-esw/ESW2011.html

September 2011
Sheraton
Toronto, Ontario, Canada
http://www.ieee-pcic.org/Conferences/2011_Toronto/index.html

March 2012
Mayfield Inn
Edmonton, Alberta, Canada
www.ieee.org/estmp

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 vs current source
  - Rectifiers
    - Passive / Active Front End
    - Multi-pulse
  - Inverters
    - 2 Level
    - Multilevel
    - Series H bridge

Outline

Adjustable Speed Drive Designs (continued)

- Typical voltage source topologies
- Typical current source topologies

- Adjustable Speed Drive History
  - Need for a performance standard
- An adjustable speed drive system
- IEEE 1566

– Purpose of the standard

– Standard overview

- 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 allows us to adjust the speed of an electric motor (by varying the frequency of the power delivered to the motor).

MOTOR SPEED = 120 x F / P

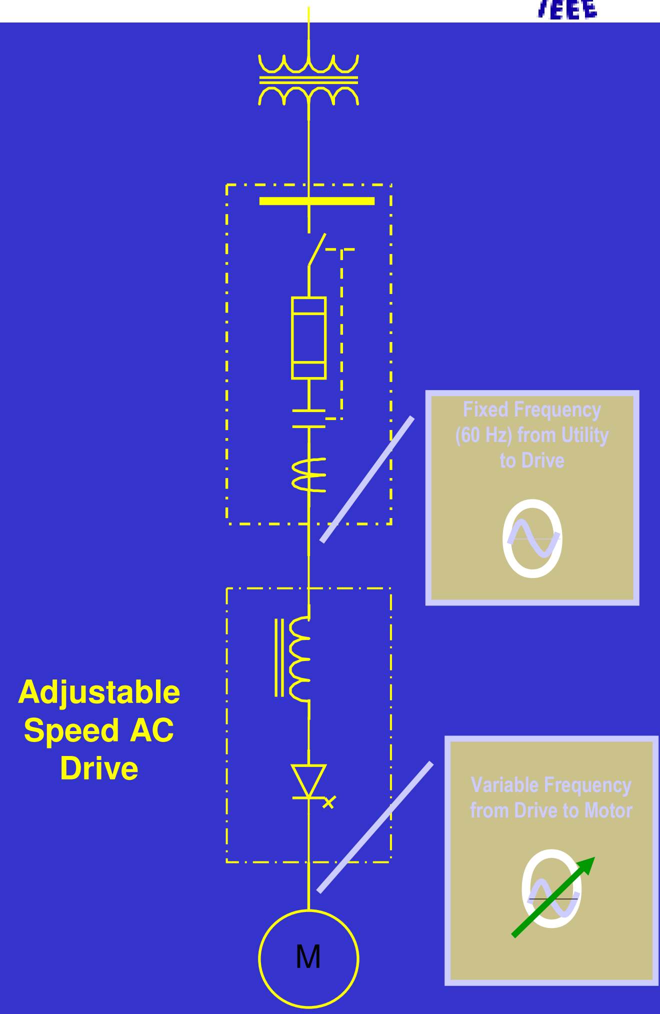
$$\text{MOTOR SPEED} = \frac{120 \times F}{P}$$

120 = constant

F = supply frequency (in cycles/sec)

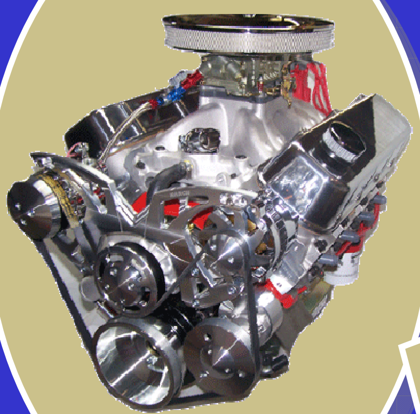
P = number of motor winding poles

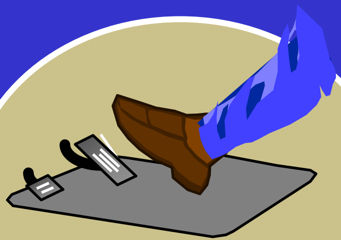
- Both the "120" and "P" portions of the formula are fixed, the only item we can use to adjust the motor speed is "frequency"



What is a "Drive"?

Let's relate this to the operation of the gasoline engine of a car:





What is a "Drive"?

With a fixed (voltage, frequency) supply source, a rotational motor stator flux occurs in an AC Induction motor stator proportional to the

- supply frequency
- # of motor poles

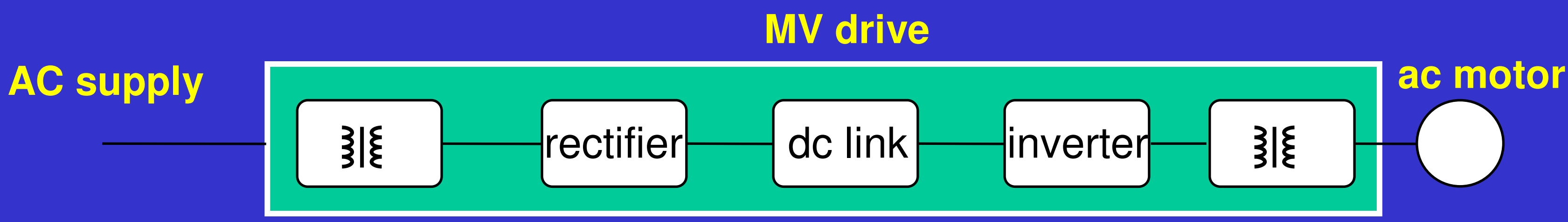
Induction motor rotor will follow this stator magnetic field with slip depending on load

i.e. Near 3600 rpm unloaded
3560 rpm at rated load

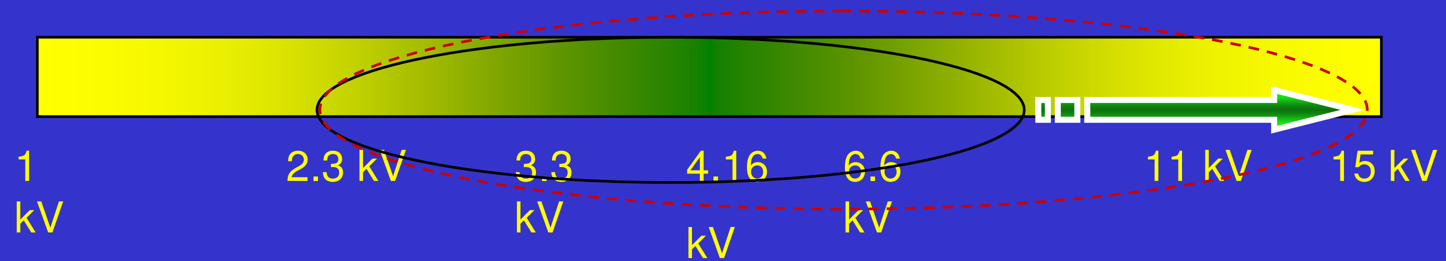
	FREQUENCY (Hz)	
	50	60
POLES	SYNCHRONOUS RPM	
2	3000	3600
4	1500	1800
6	1000	1200
8	750	900
10	600	720
12	500	600
14	429	514

RPM = 120 x f / P
RPM = revolutions per minute
f = frequency of the stator current in Hz
P = number of motor magnetic poles

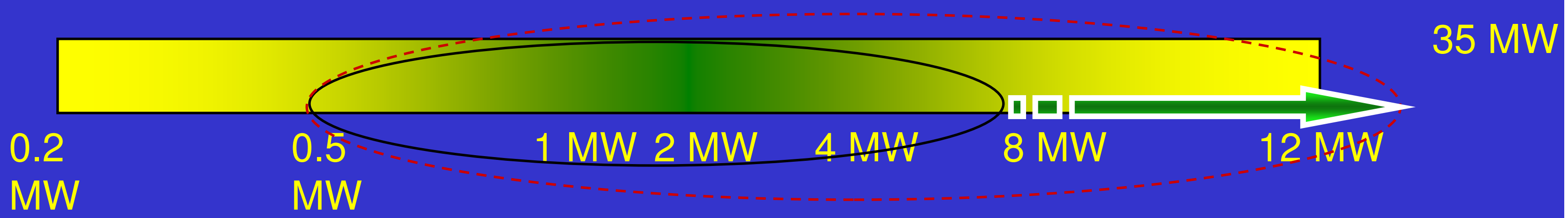
AC ASD Medium Voltage Drives



Voltage Range



Power Range



Why Use Adjustable Speed Drives ?

In general, ASDs are used to

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

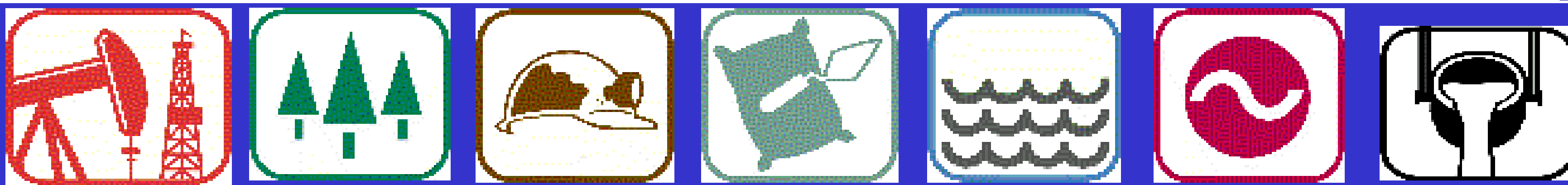
Why Use Adjustable Speed Drives ?

- 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

Why Use Adjustable Speed Drives ?

- 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
- Regenerative braking
- Environmental compliance requirements. Many SCR / RTO pollution control equipment require the use of a VFD to operate optimally.

Where are MV Drives Used?



Petrochemical
Pipeline pumps
Gas compressors
Brine pumps
Mixers / extruders
Electrical submersible pumps
Induced draft fans
Boiler feed water pumps

Cement
Kiln induced draft fans
Forced draft fans
Cooler baghouse fans
Preheat tower fans
Raw mill induced draft fans
Kiln gas fans
Cooler exhaust fans
Separator fans

Forest Products
Fan pumps
Induced draft fans
Boiler feed water pumps
Pulpers
Refiners
Kiln drives
Line shafts

Water / Waste Water
Raw sewage pumps
Bio-roughing tower pumps
Treatment pumps
Freshwater pumps

Mining & Metals
Slurry pumps
Ventilation fans
Descaling pumps
Conveyors
Cyclone feed pumps

Commercial
Airport Cogeneration
Hospital Cogeneration
University Cogeneration
OEM Chillers/Compressors

Electric Power
Feed water pumps
Induced draft fans
Forced draft fans
Effluent pumps
Compressors

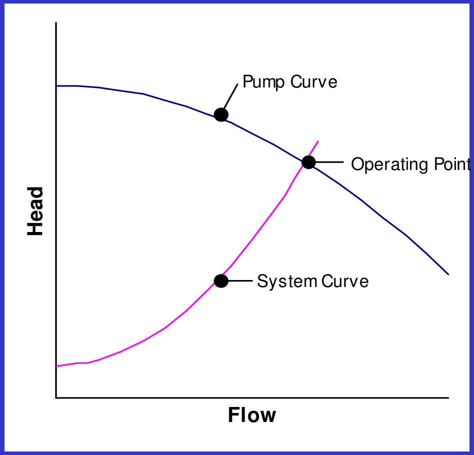
Marine Applications
Ship propulsion
Thrusters
Dredging Pumps

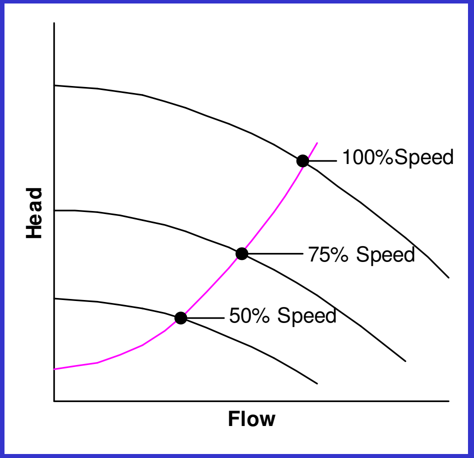
Subsea
Petrochemical applications
Multiphase Pumps
Injection Pumps
Production Pumps
Compressors

Miscellaneous
Test stands
Wind tunnels
Agitators
Rubber mixers
Thermal Oxidizers

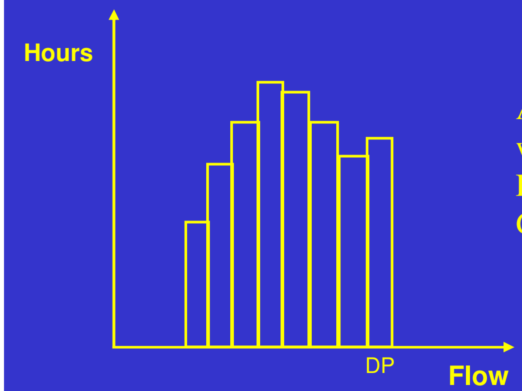
AC Induction Motor Operation with ASD Pump Example

- 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”
- Adjustable speed operation allows flow to be controlled by shifting the operating point without energy losses associated with restricting flow external to the pump
- In some applications, control valves are not a practical option – slurry pumps due to excessive wear

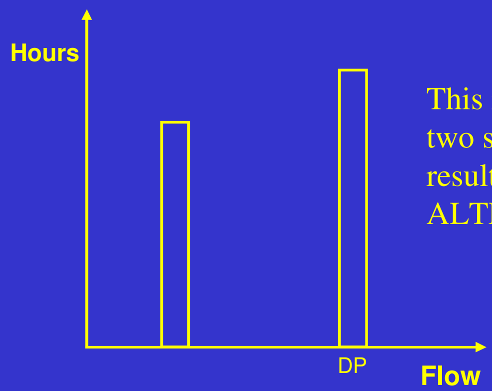




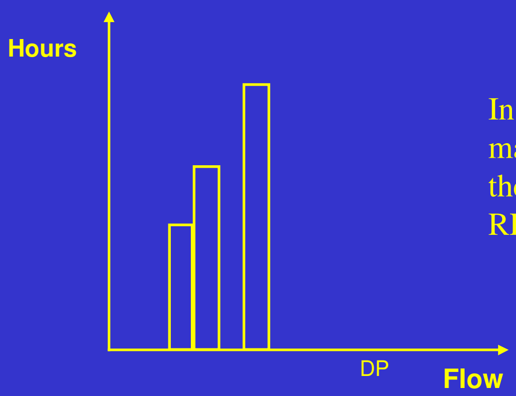
Energy Savings Considerations



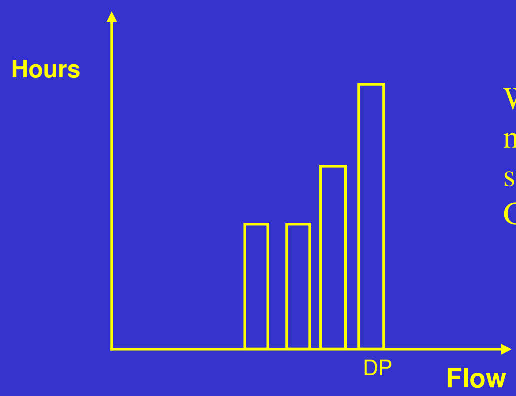
A high Degree of Variability will typically result in significant Energy Savings
GOOD CANDIDATE



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

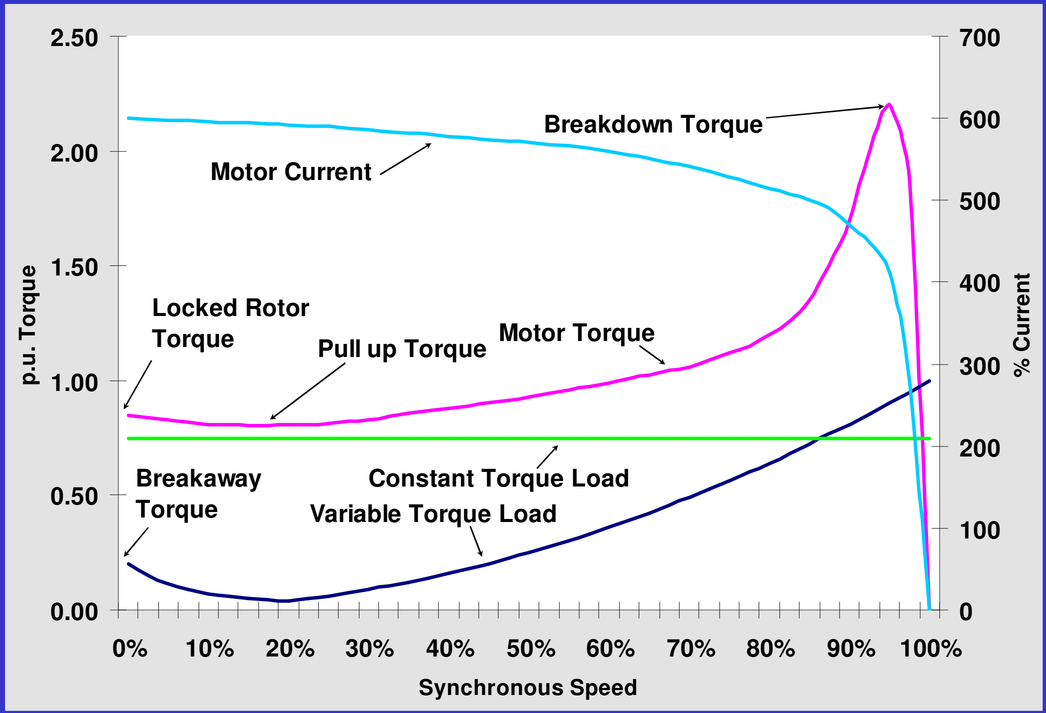
Improve AC Induction Motor Performance

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

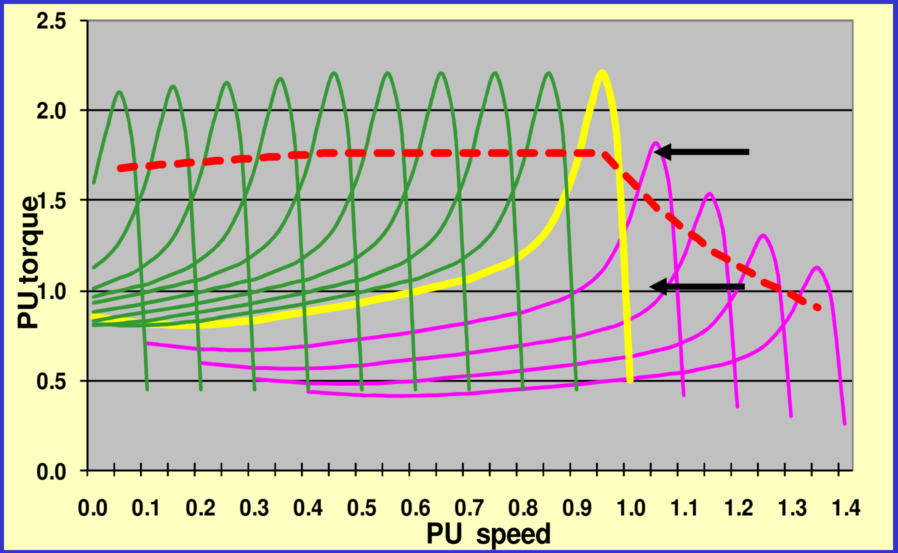
Operation on ASD

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

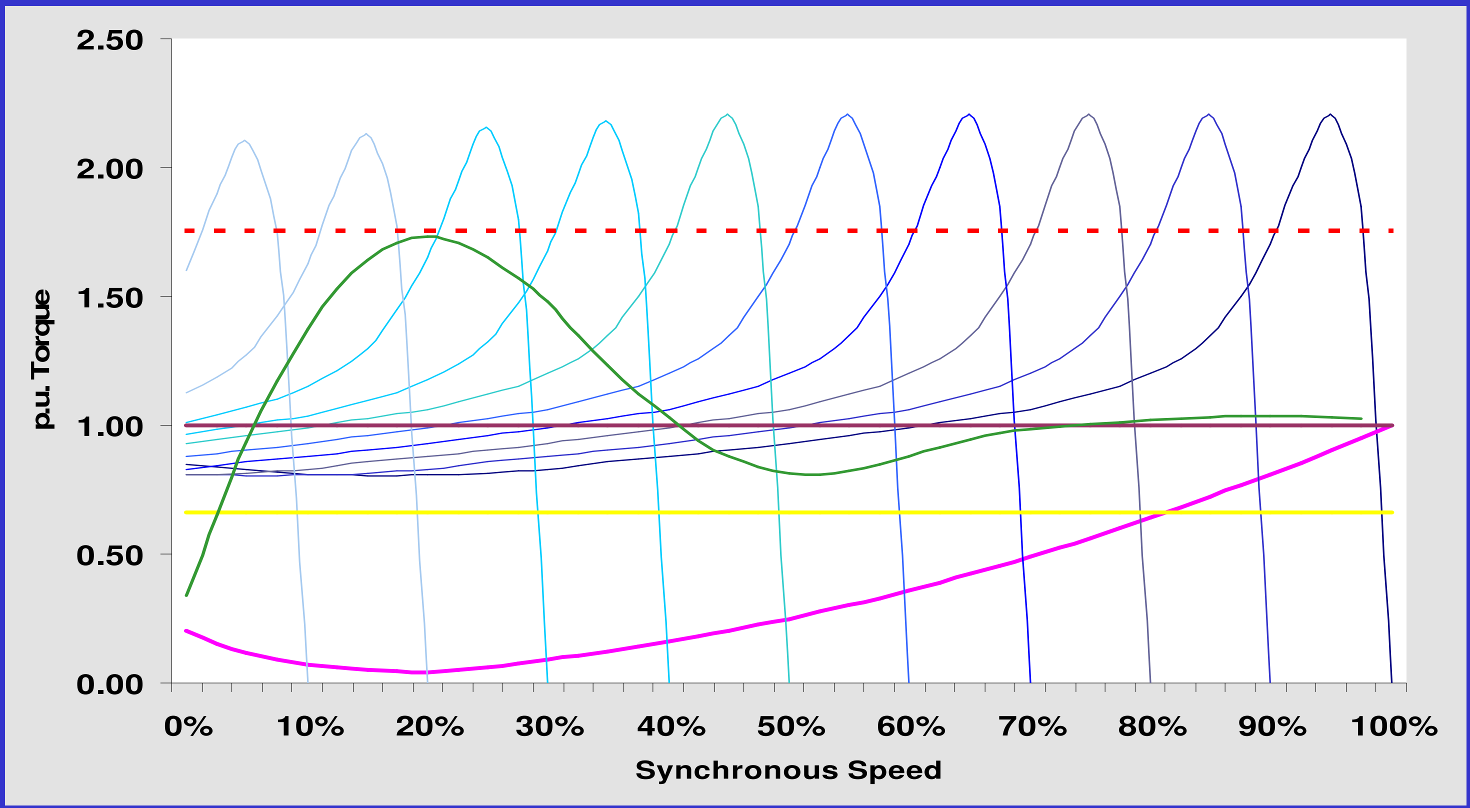


AC Induction Motor Operation with Adjustable Speed Drive

- 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

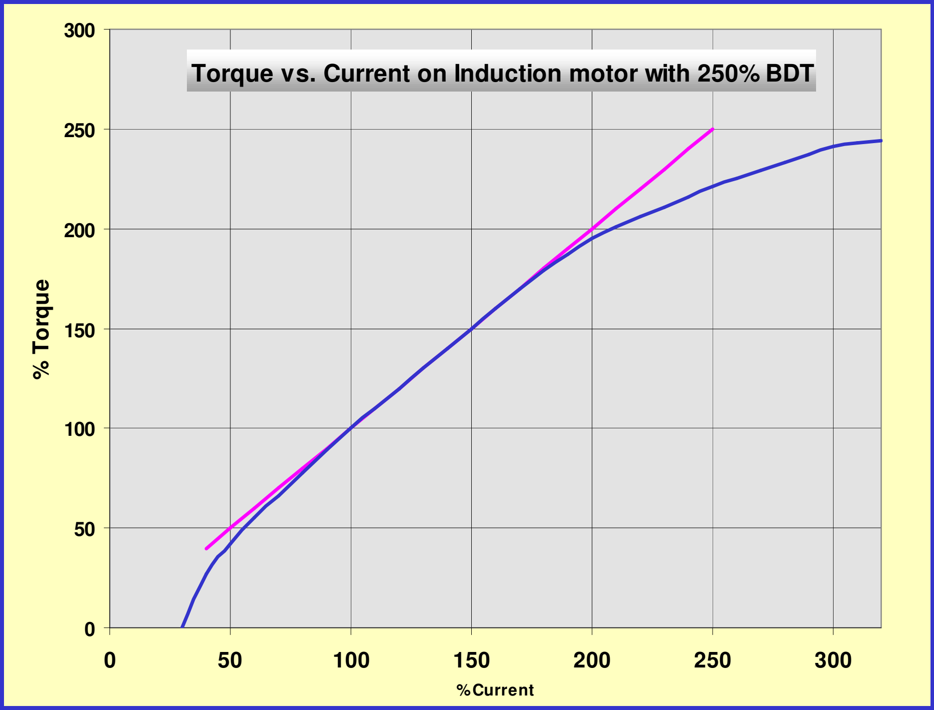


Motor & Load Torque Evaluation



High Torque Operation

- Operation of Induction Motor on ASD
  - 80 - 90% of break down torque can be realized
  - Starting current is proportional to the torque in ranges of 50 to 200%
  - Drive must be selected 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

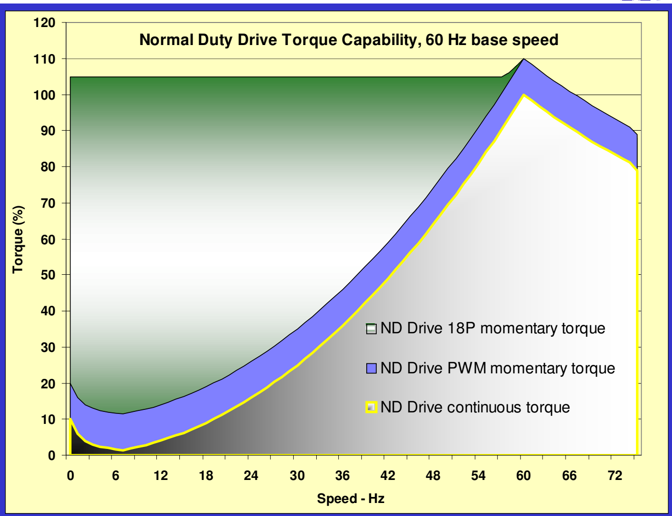


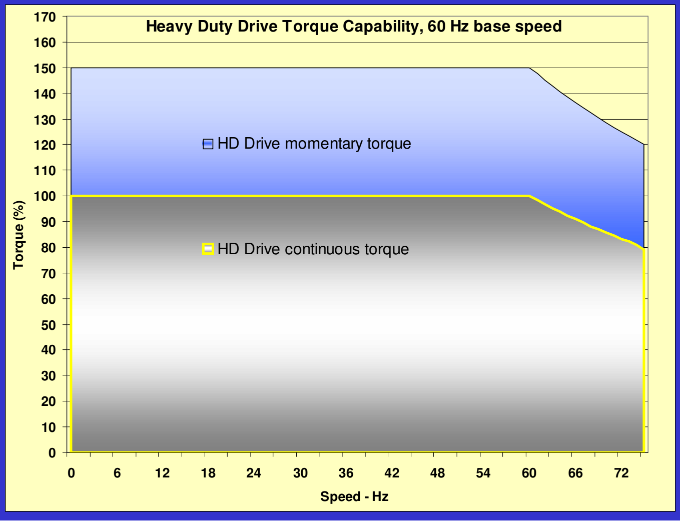
Load Requirements

Load Profile is the prime consideration when sizing an ASD

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

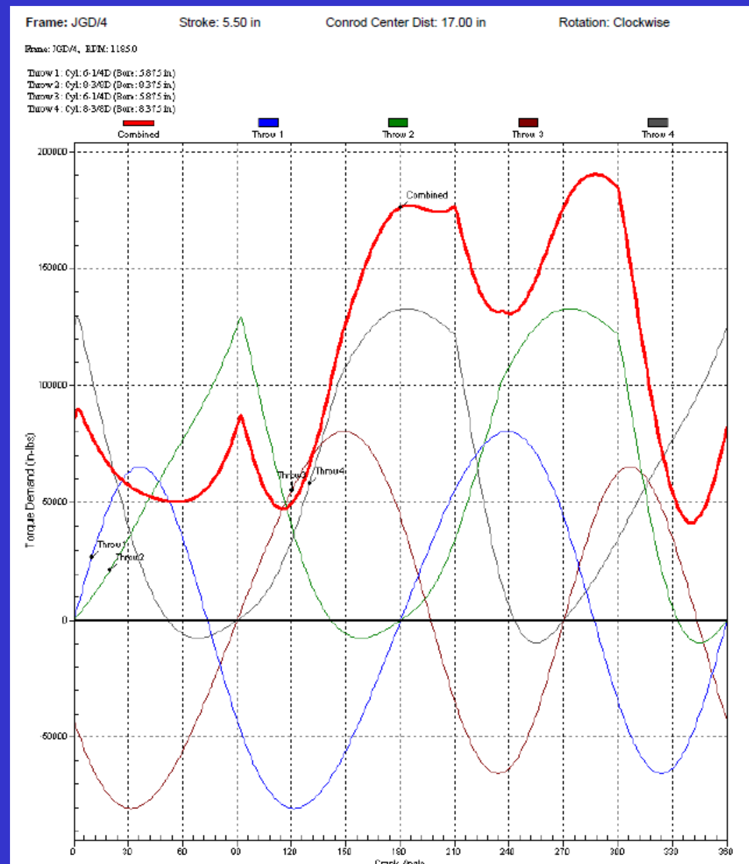




Reciprocating Compressors

- 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

Apron Feeder / Conveyor Applications

Constant torque application

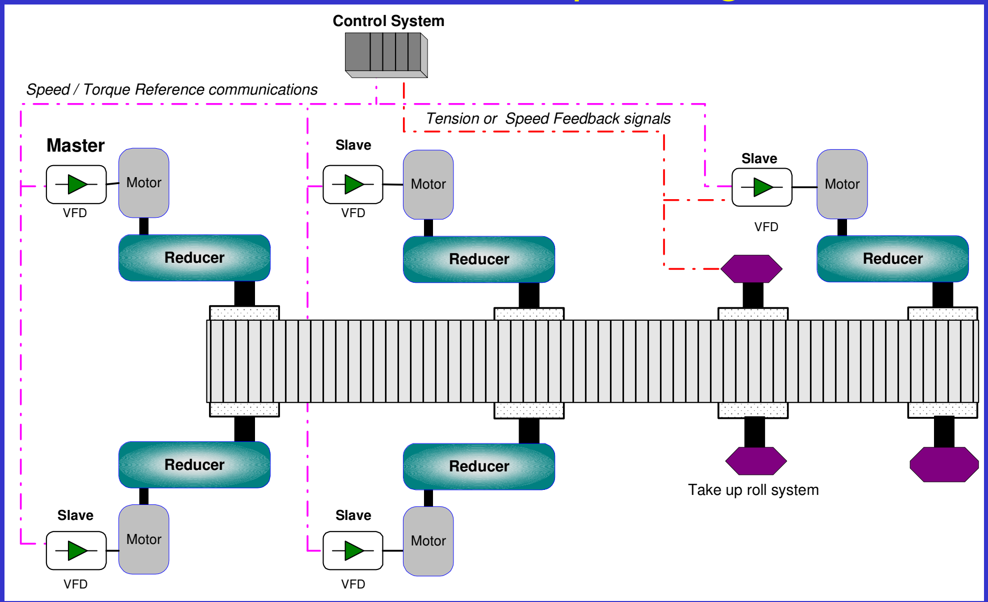
Rated torque is required over 0 -100% speed

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

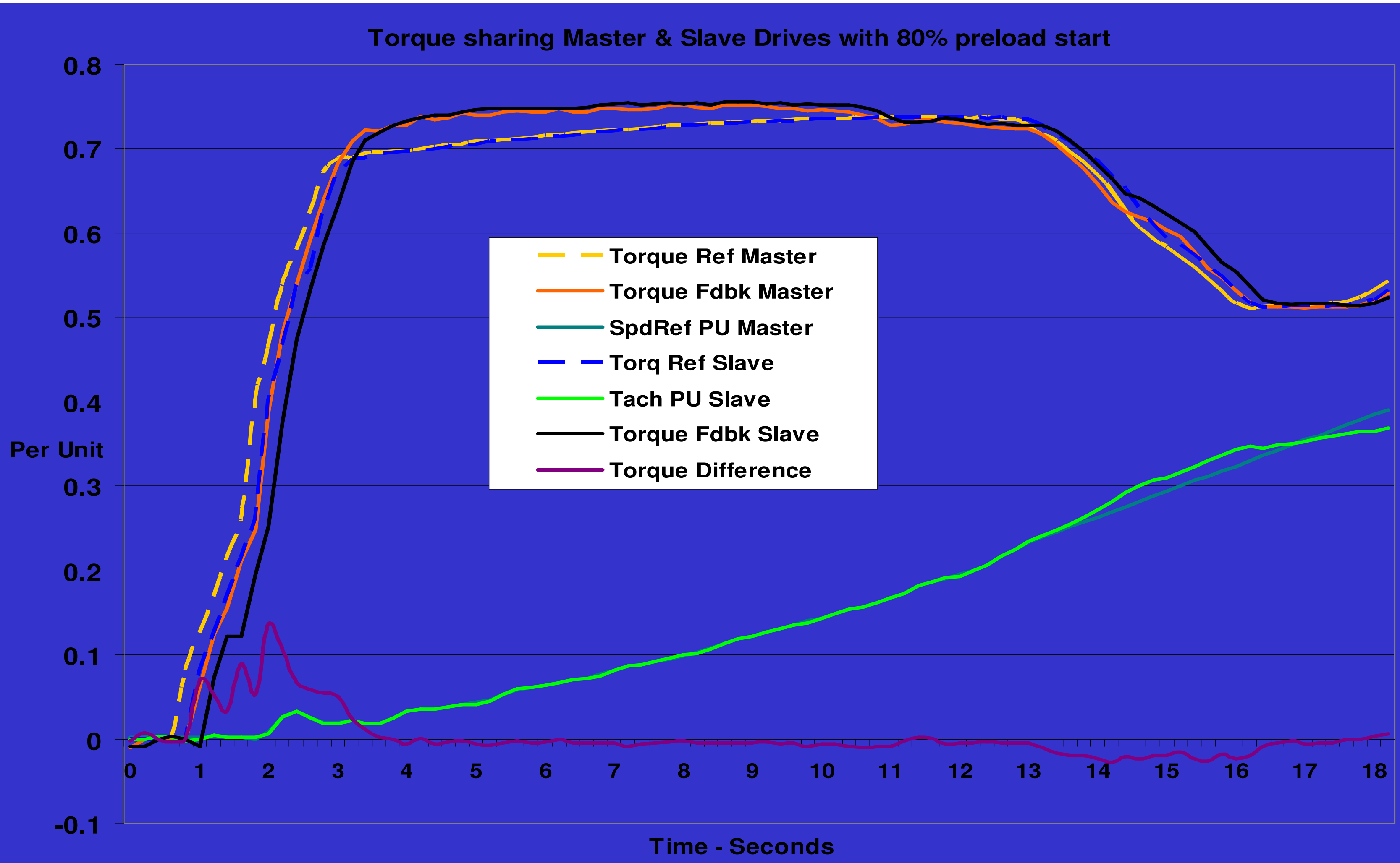
- Uphill, downhill, level or combination of these
- Different lengths, tension control systems
- Single or multi-motor
- Drive pulley arrangement



Affected parameters

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

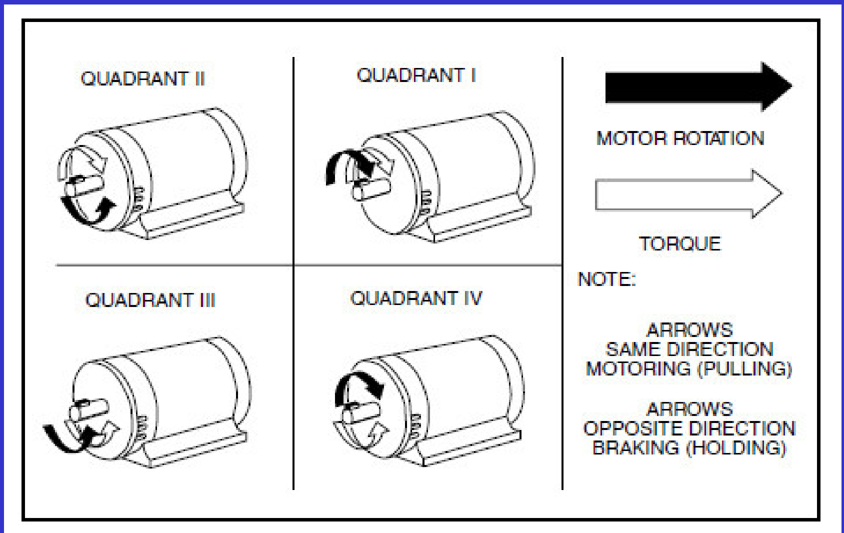
Load Sharing

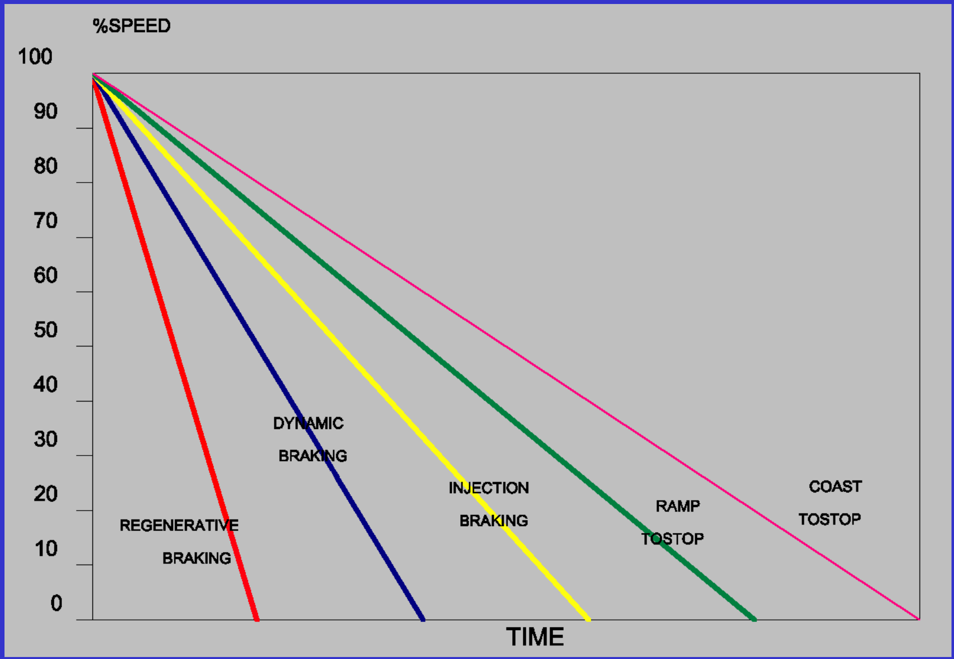


Regenerative Braking

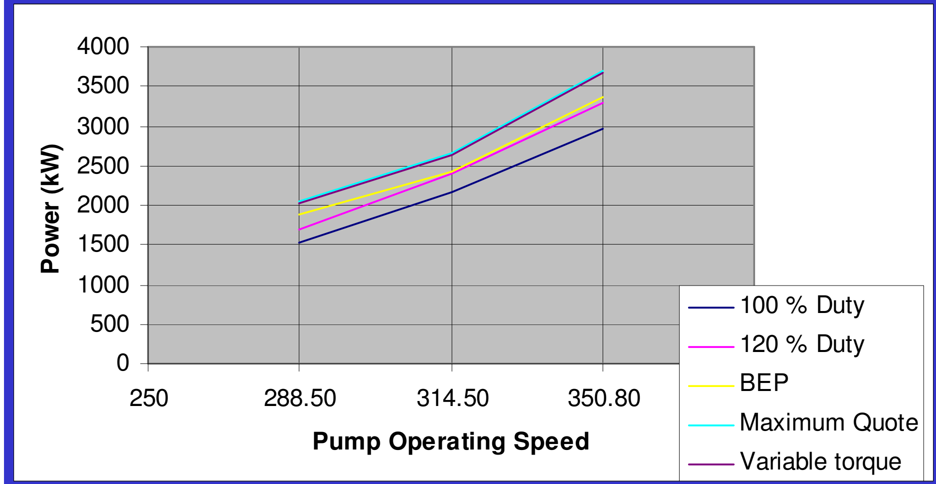
Overhauling loads are the most demanding braking application. Braking energy equal to or even possibly exceeding the motoring requirement are possible in applications such as conveyors, slurry pumps, etc. Regenerative Braking is the best method to deal with this.

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



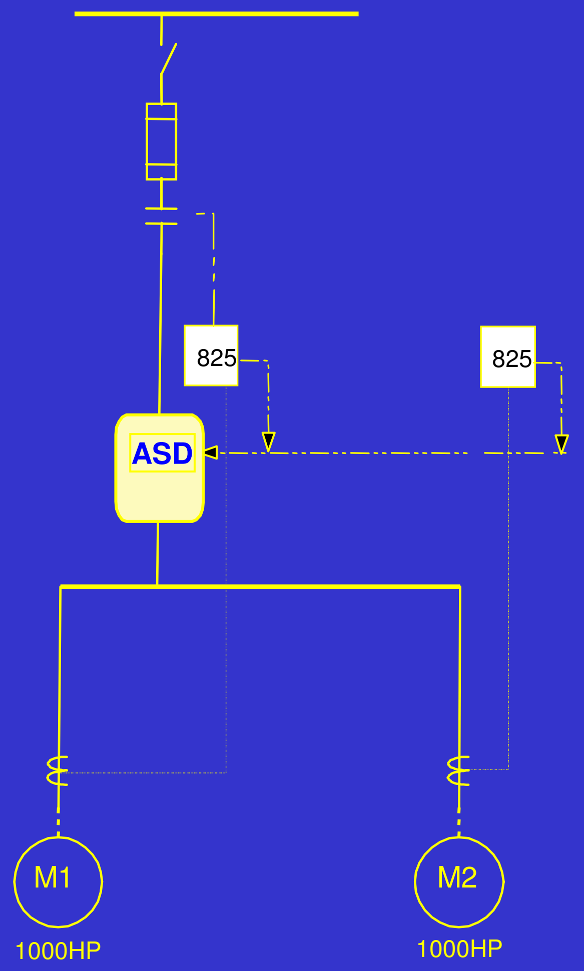


Slurry Pumping / Hydro-transport



- 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

Multi-motor configuration



Reduced initial cost

Simultaneous speed control

Drive sized for total HP

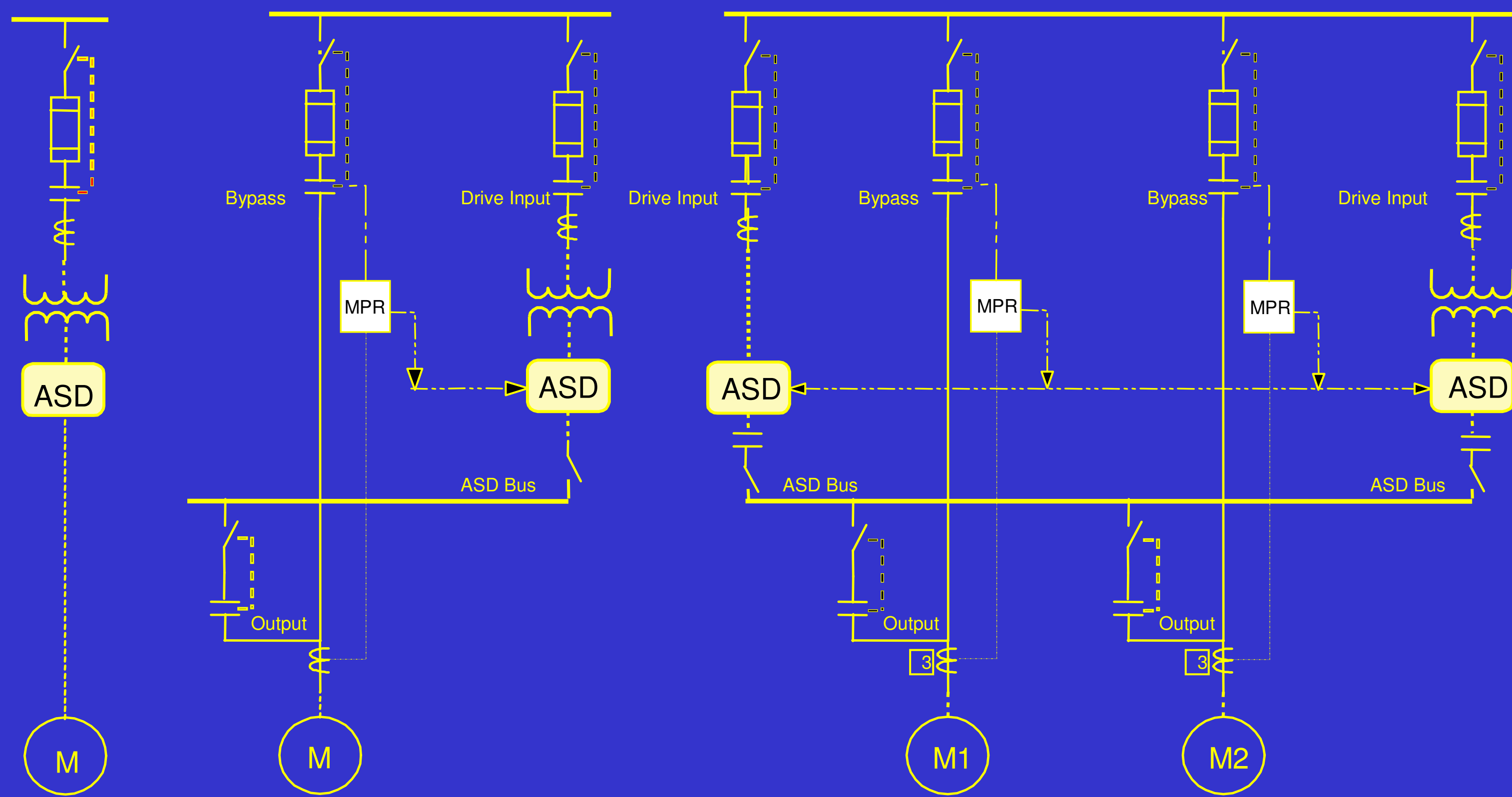
Motors can be mechanically coupled or separate

- 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

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

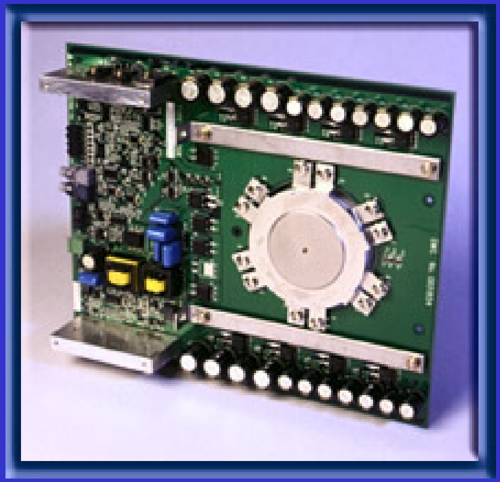
- Low Total Cost of Ownership
- High Efficiency
- Power Factor
- Dynamic Response
- Features

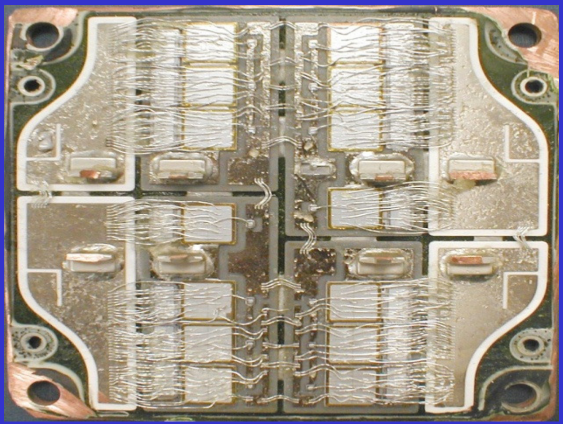
Cost Effective

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

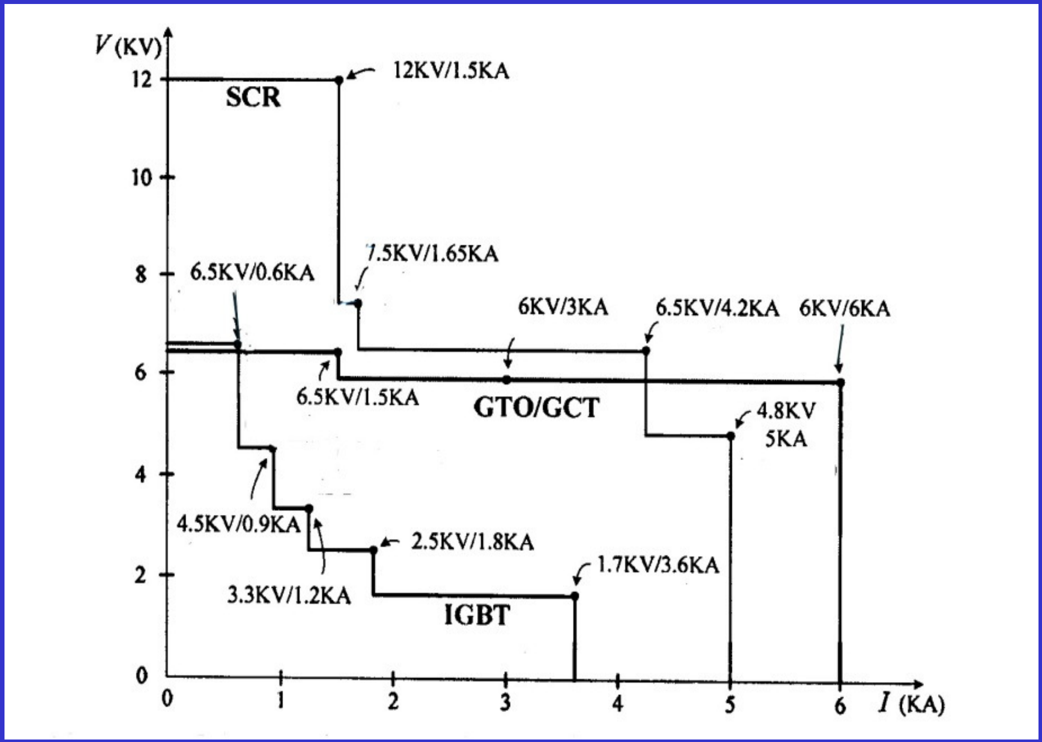




Semiconductors

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



Symmetric Gate Commutated Thyristor (SGCT)

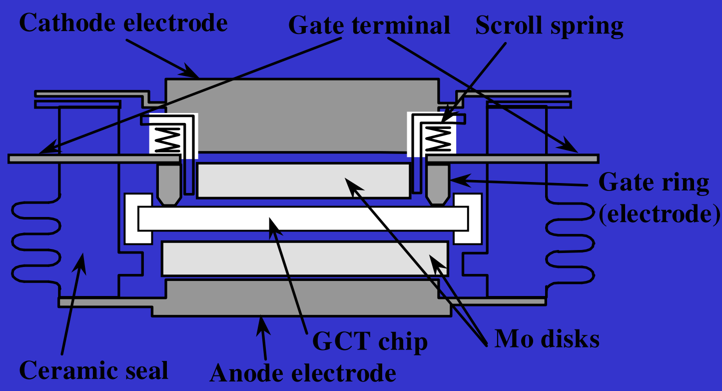
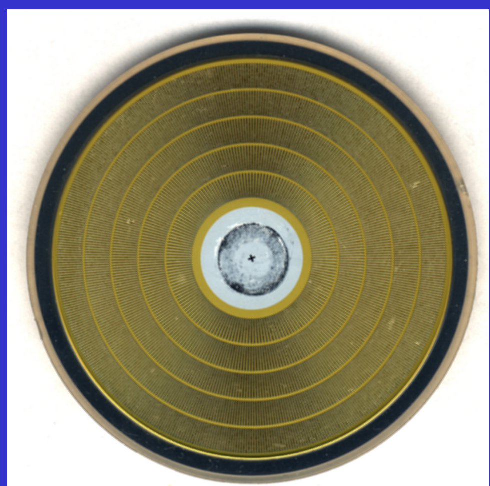
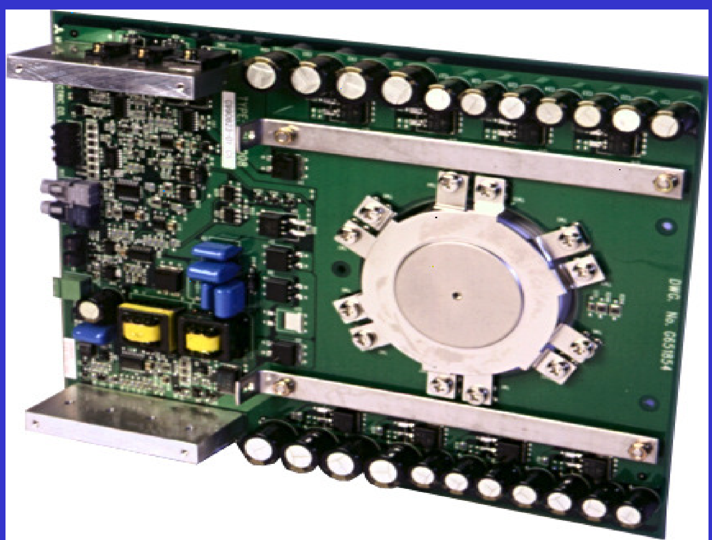


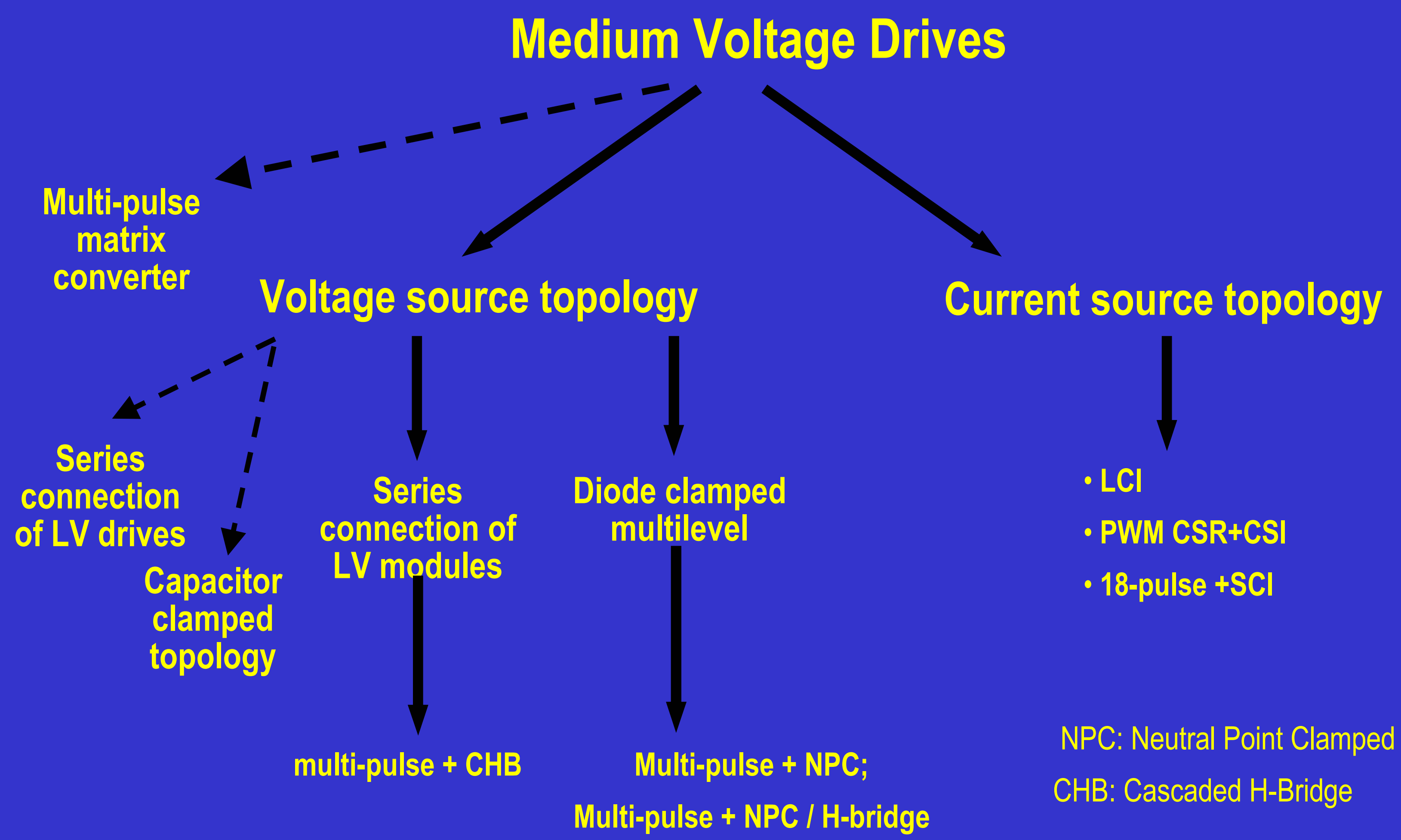
Fig. 4. Cross-sectional structure of SGCT.

- Device is utilized at half of the rated design - 50 % margin
- Devices can be used in series
- Dual Sided Cooling
- Superior Thermal Management to the internal wafer
- IGCT similar to SGCT except blocks in one direction only

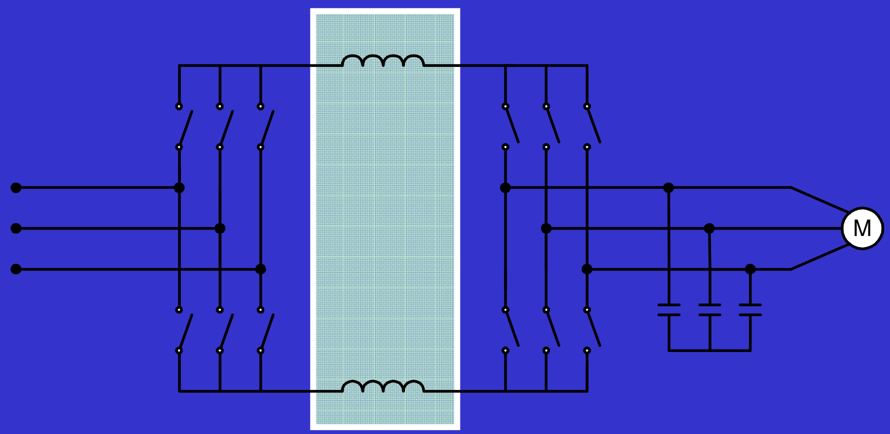


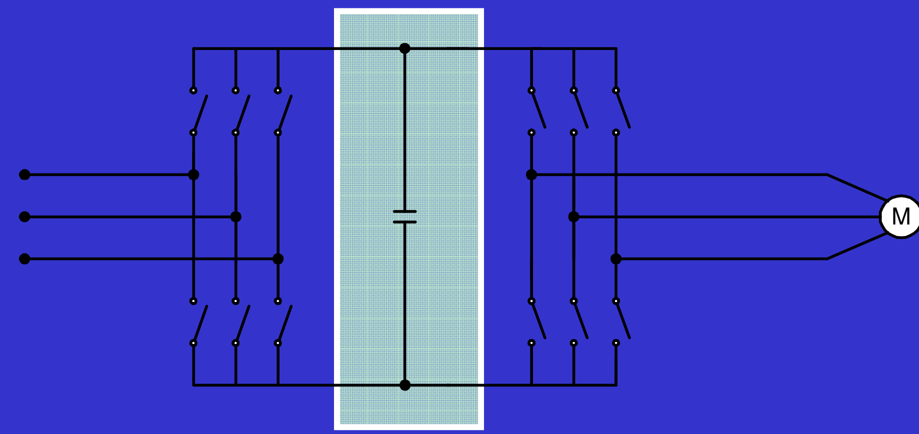


Topology fundamentals: classification

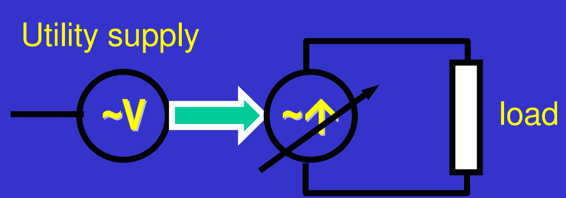


Topology fundamentals: CSI & VSI





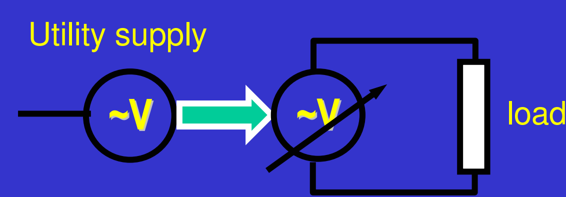
Current Source Topology



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

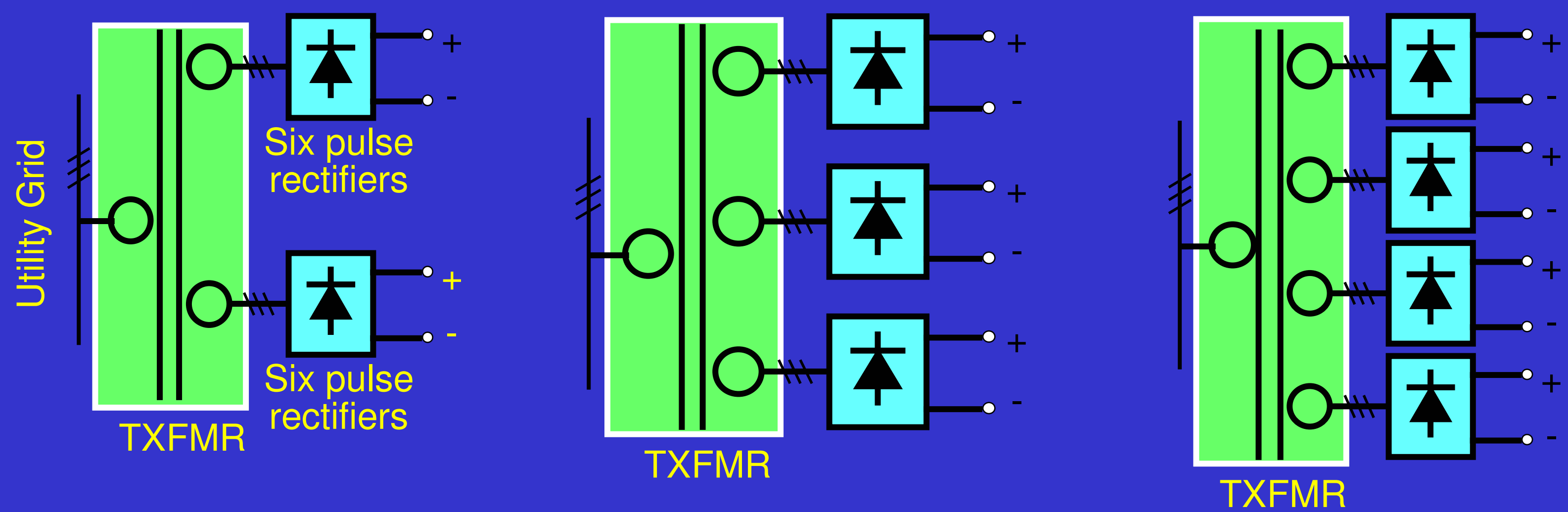
Passive Front End

- 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

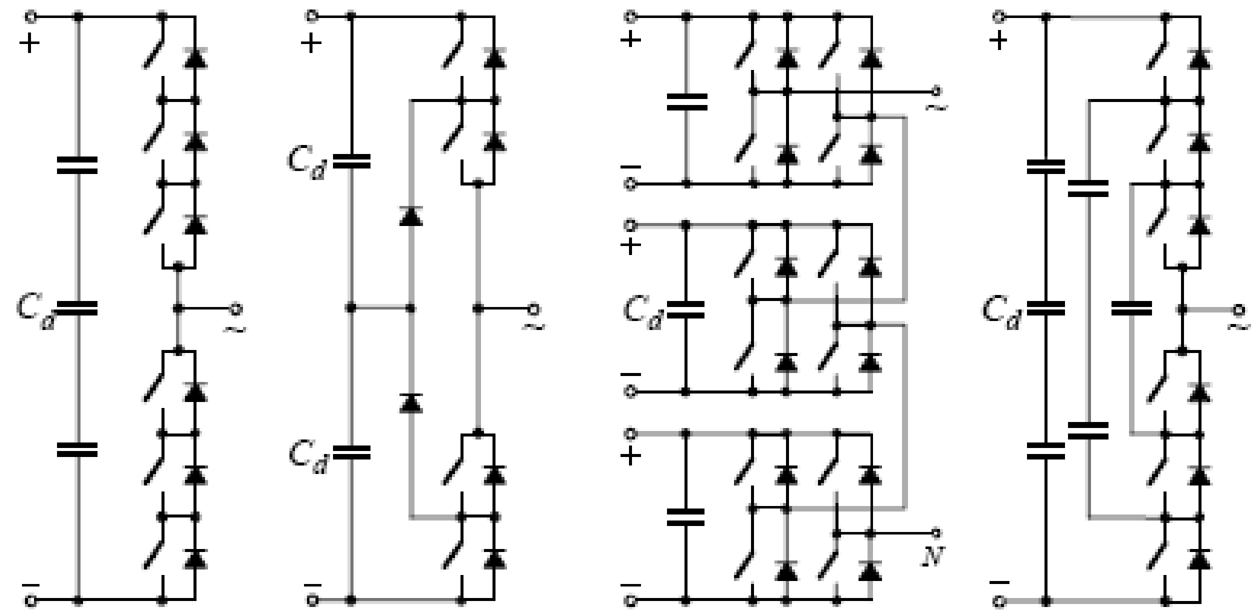
$\delta = 20^o$

(c) 24-pulse rectifier

$\delta = 15^o$

Transformer is also used to deal with common mode voltage

Topology Fundamentals - Inverters



Two Level Inverter

Neutral Point Clamped (NPC) Inverter

Cascaded H-bridge (CHB) Inverter

Flying Capacitor Inverter

- Higher output voltage w/o devices in series

Topology Fundamentals – Voltage Source Drives

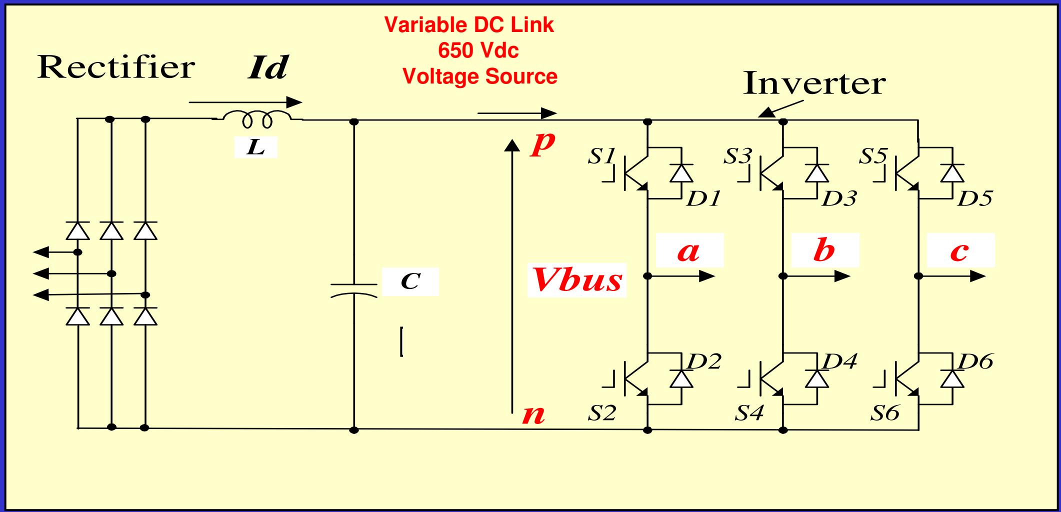
Variable Voltage Inverter (VVI)

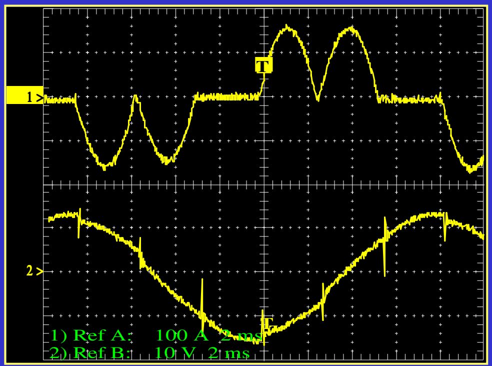
Voltage Source Inverter (VSI – PWM)

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

LV VVI 6 Step Base Characteristics

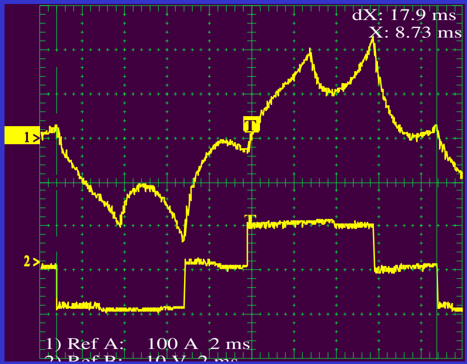
Input:

SCR bridge rectifier

Variable DC Link bus voltage

Output:

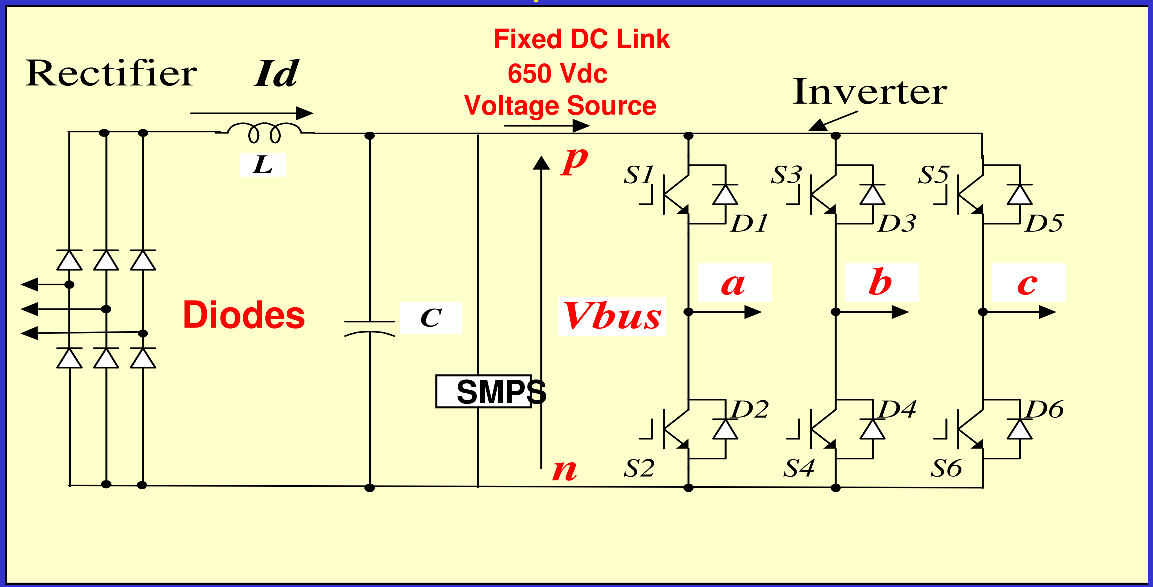
Inverter switches to obtain required waveform orientation

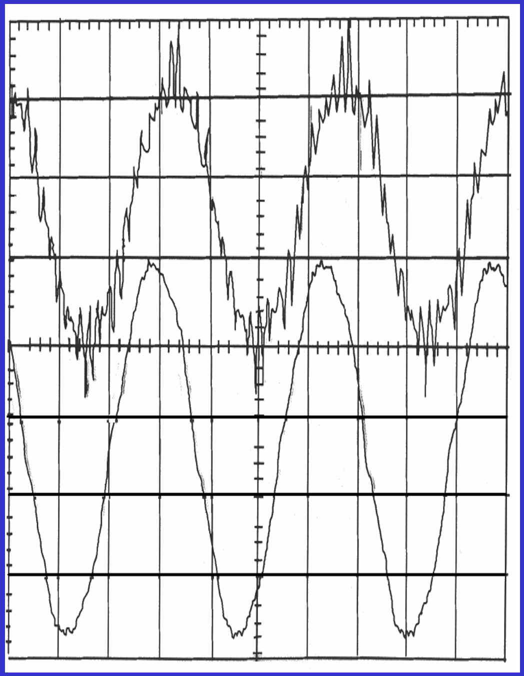


480 Volt Output
Top: Current waveform
Bottom: Voltage waveform

Topology Fundamentals – Voltage Source Drives

6 Pulse Rectifier, DC Link capacitor & IGBT Inverter





480 Volt Output
Top: Current waveform
Bottom: Voltage waveform

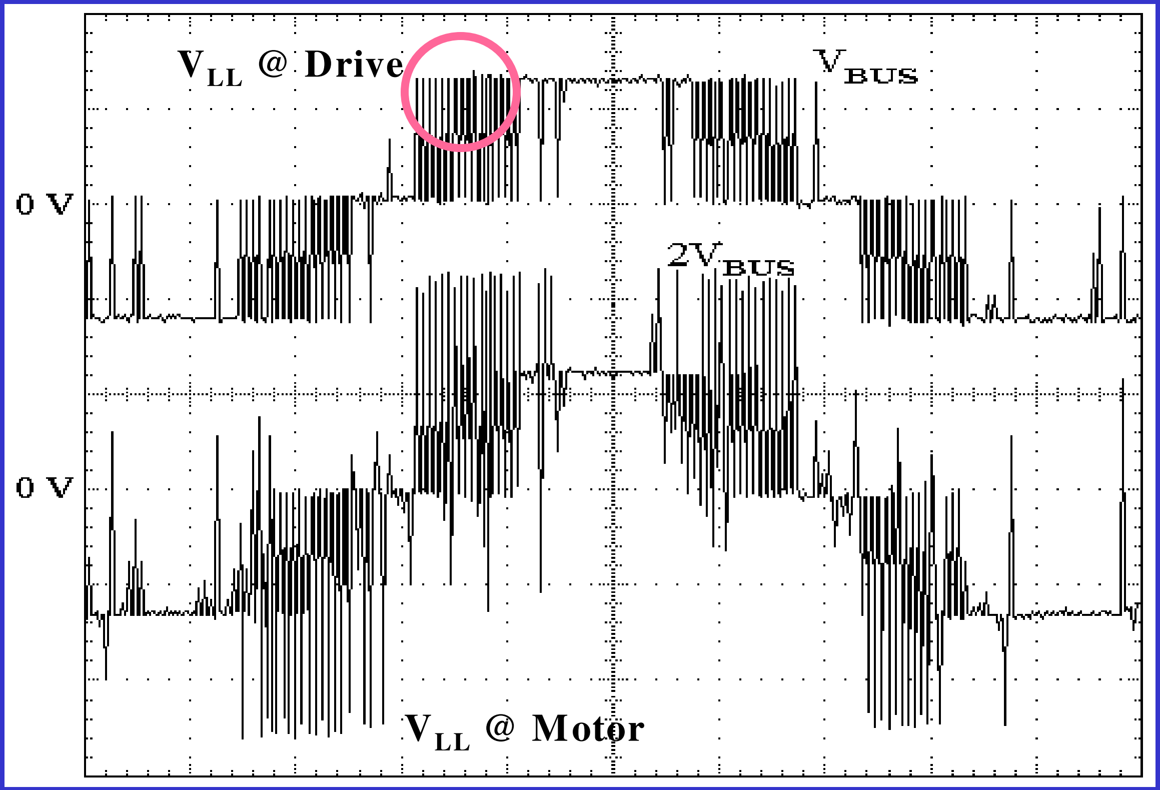
LV VSI PWM 2 Level Base Characteristics

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

Transient Peak Over-Voltages at Output

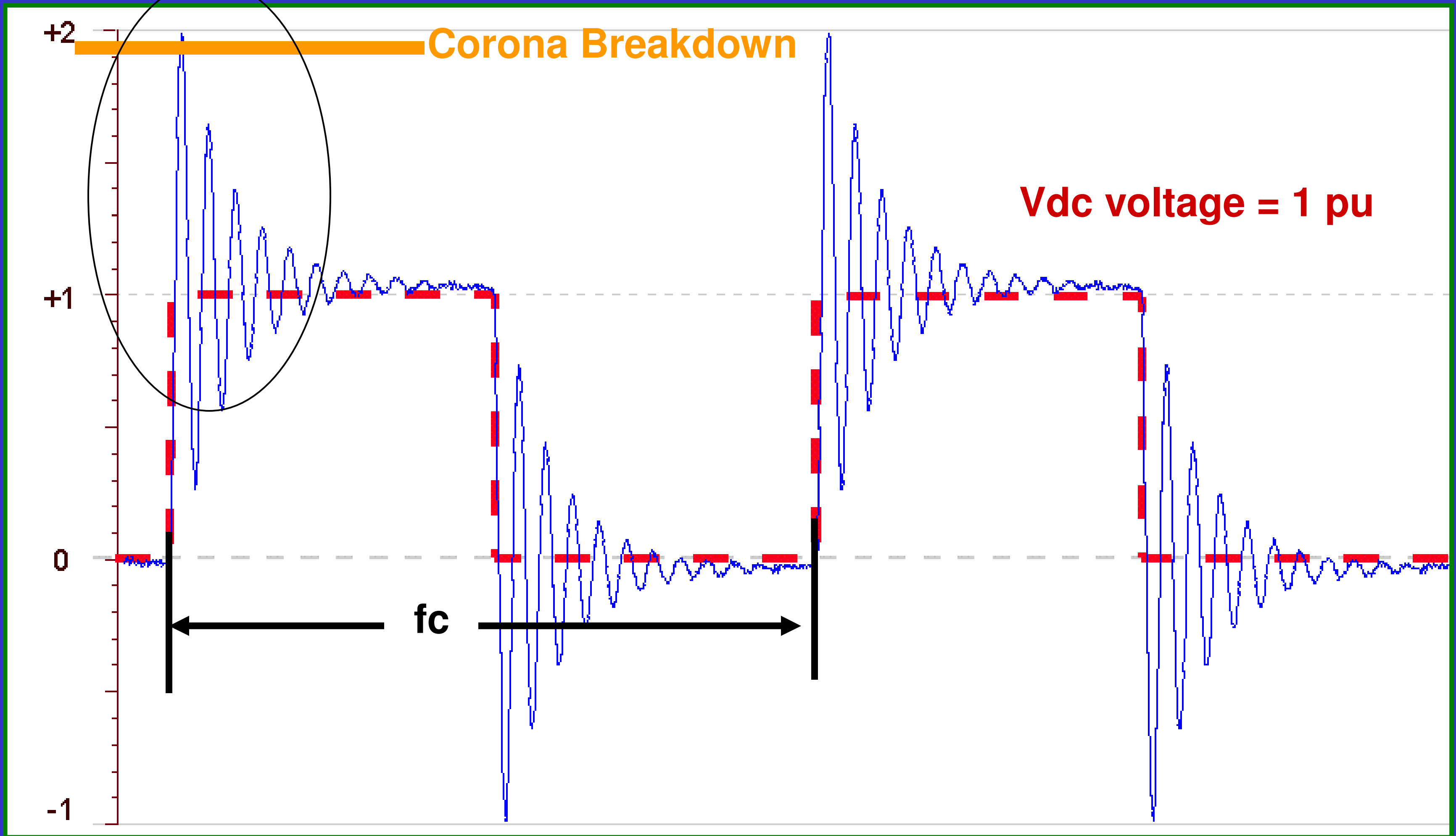
Output Voltage @ PWM Drive

Output Voltage @ Motor with Long Output Cables

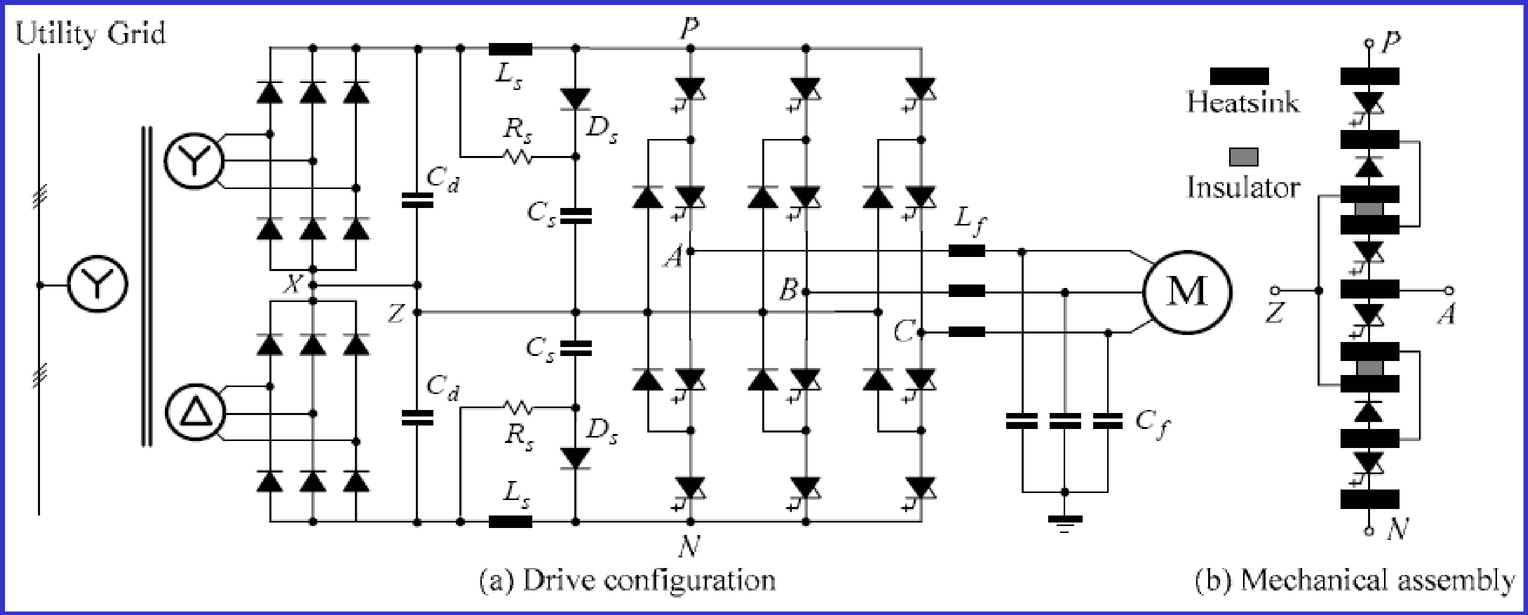


Transient Over-voltages of twice DC bus [2pu] are possible at some cable distance. Commonly known as “Transmission Line Effect”
This is due to surge impedance mismatch between Cable and Motor

Output Over-Voltage Transients at the Motor Terminals may Exceed Corona Breakdown Limits of Cable or Motor



Topology Fundamentals – Voltage Source Drives



VSI-PWM 3 Level with Output Filter Topology

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

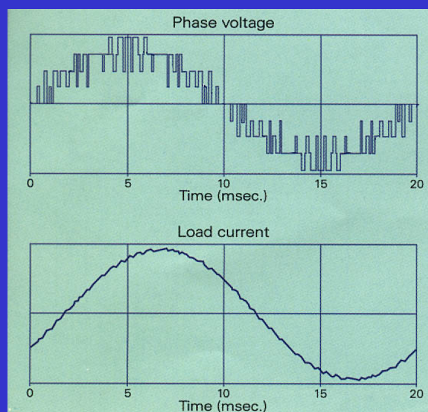
12 Pulse Rectifier

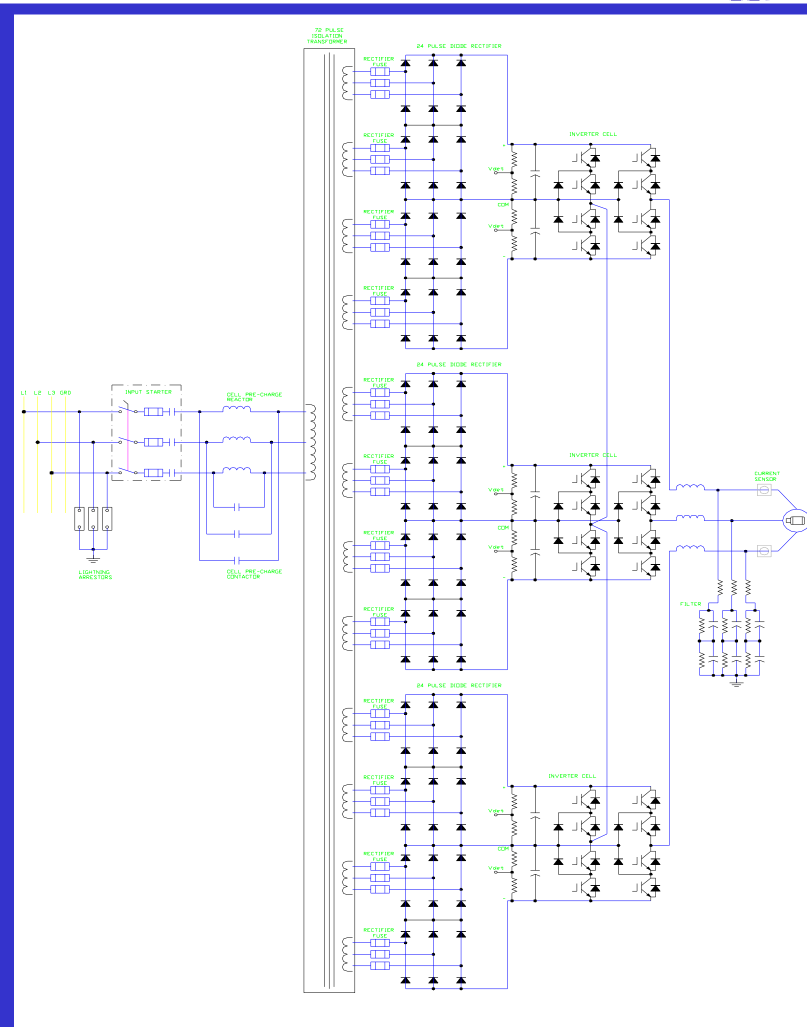
3 Level Neutral Point Clamp Inverter

Medium Component Count

GTO or IGCT Power Devices

Topology Fundamentals – Voltage Source Drives





VSI-PWM Multi Level – 5 Level shown

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

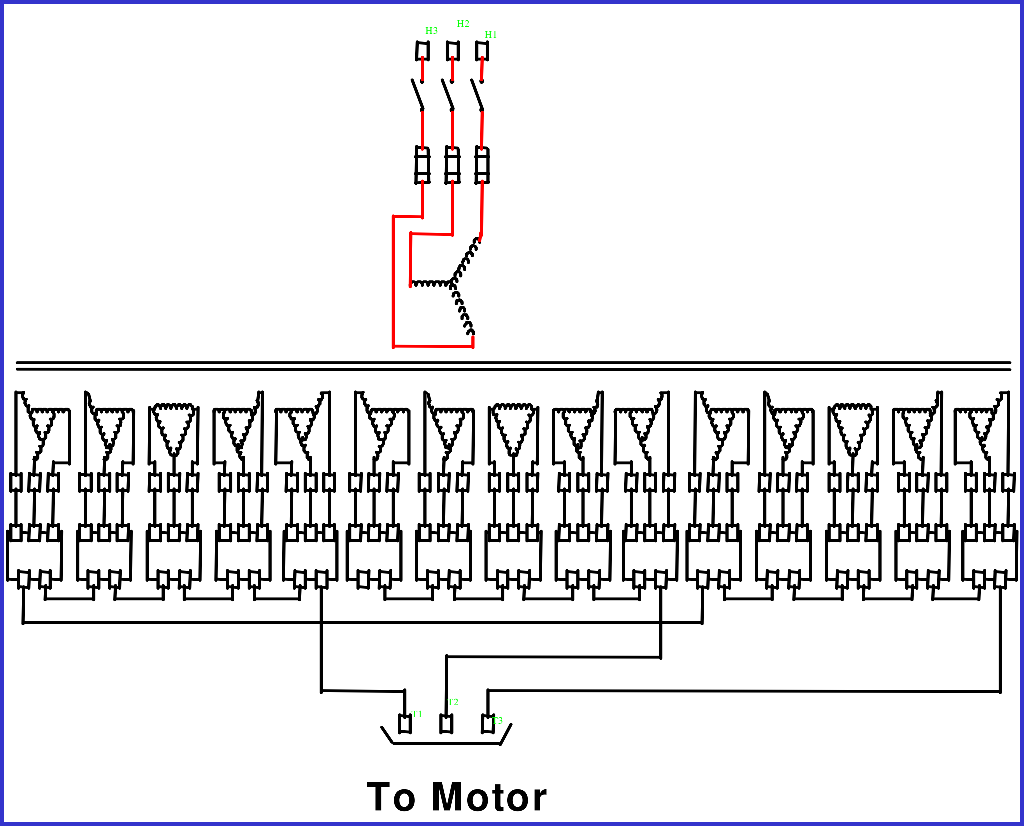
May require a new motor with up graded insulation system or output filter

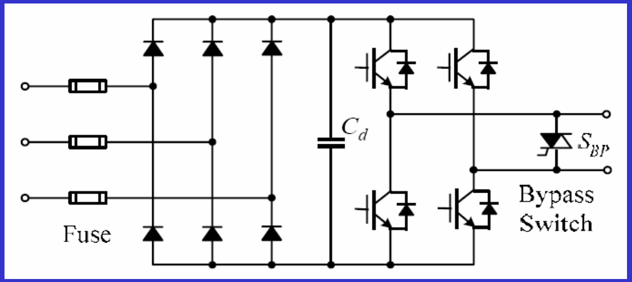
Cable length restrictions can be extended with use of output filter

No option for device redundancy

Topology Fundamentals – Voltage Source Drives

Multi-Level Cascaded H Bridge





- Low line THD – requires balanced lines
- Modular design
- Best suited for higher voltages – 13.8 kV
- Older technology
- High component count – fuses, devices
- Electrolytic capacitors replaced by dry type
- Complex close coupled isolation transformer
- Fuse coordination – primary / secondary
- Cell bypass strategy advocated which requires additional cells /contactors
- Input device often a LBS – not true E stop

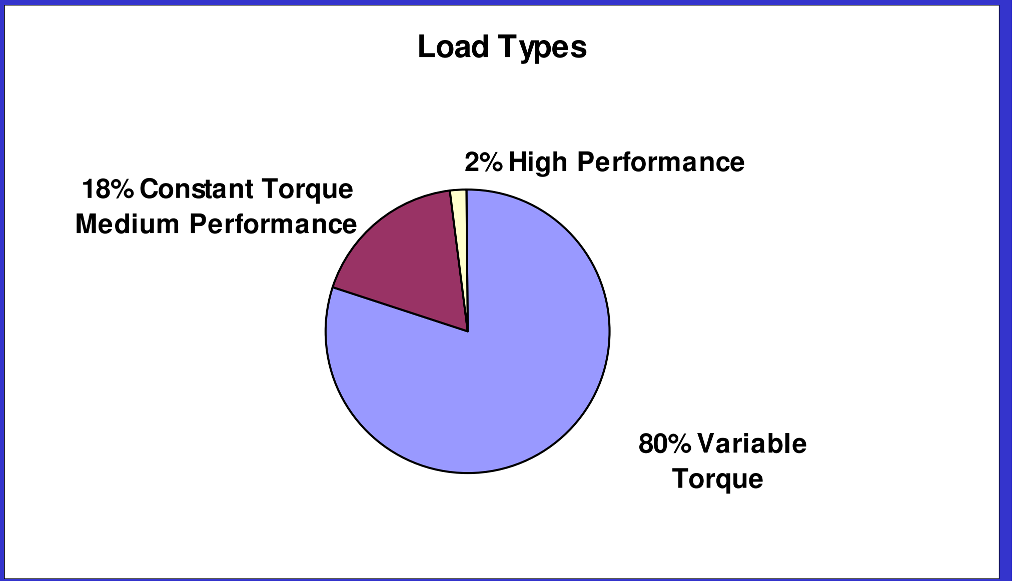
Voltage Source – Multi-Level Cascaded H Bridge

of cells versus voltage

Vmotor \ Vcell	460	630	690	750	1375
2300	3	2		2	
3300	4	3		3	
4160	5	4		3	
4800	6	4		4	2
6600		6	6	5	3
7200		7	6	6	3
10000		9			4
13800					6
14400					6

Performance

- High Dynamic response
- Supersynchronous operation



Topology Fundamentals – Current Source

Load Commutated Inverter (LCI)

Capacitor Assisted Current Source Inverter (CACSI)

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

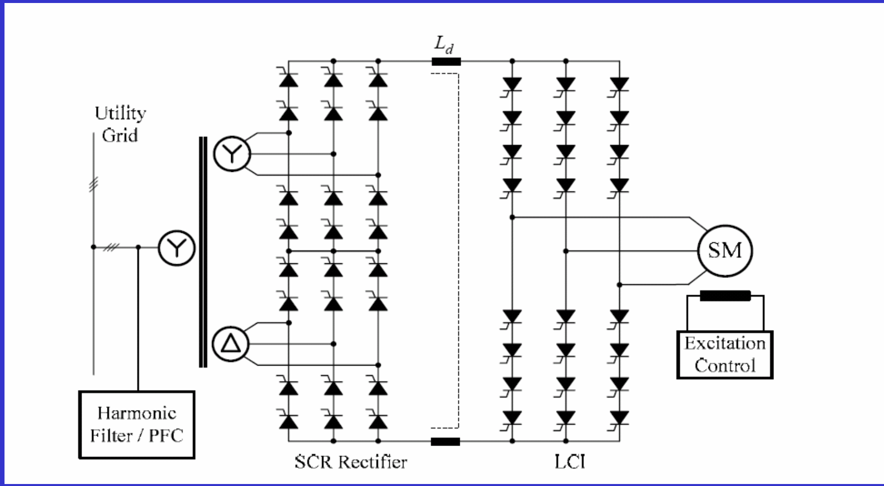
Current Source PWM Rectifier & PWM Inverter (CSI & CSR PWM)

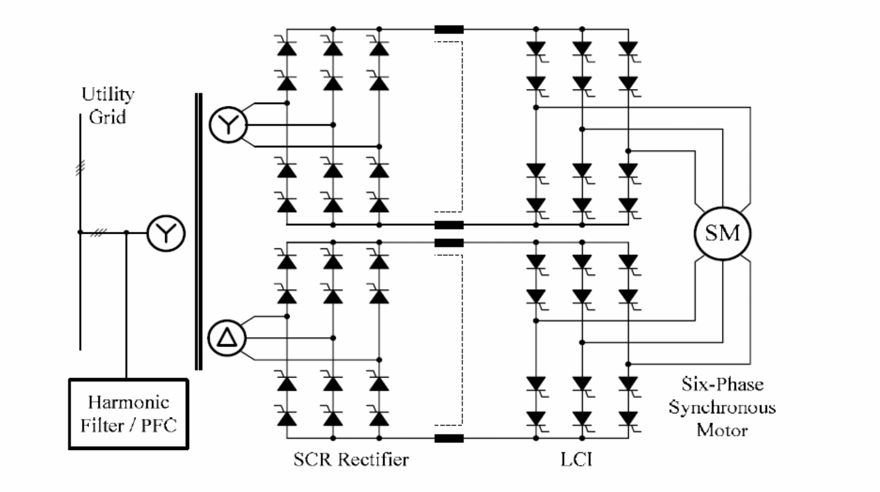
- Introduced in 2000
- CMVE addition in 2004

Topology Fundamentals – Current Source

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





Topology Fundamentals – Current Source

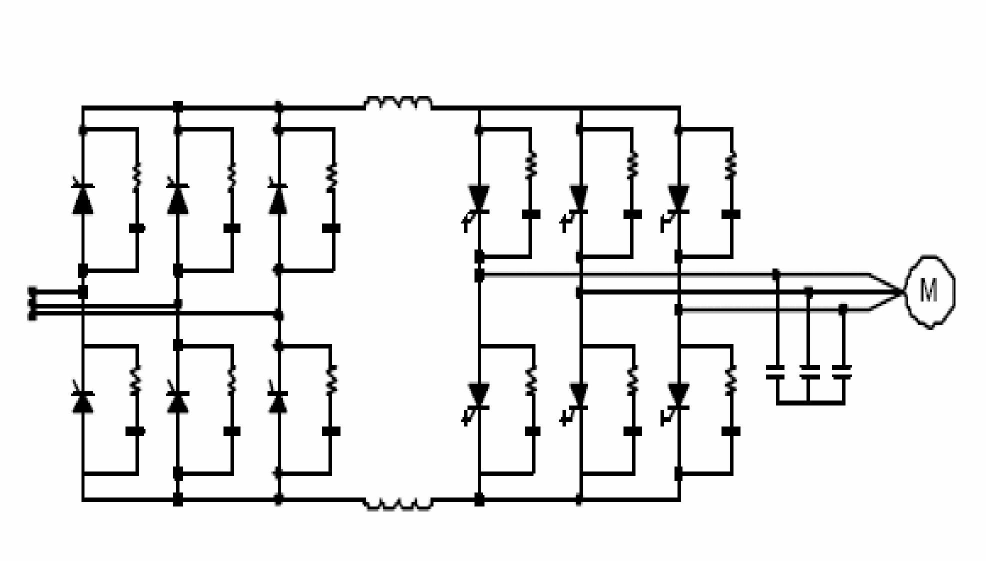
Capacitor Assisted Current Source Inverter (CACSI)

- 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

Topology Fundamentals – Current Source

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

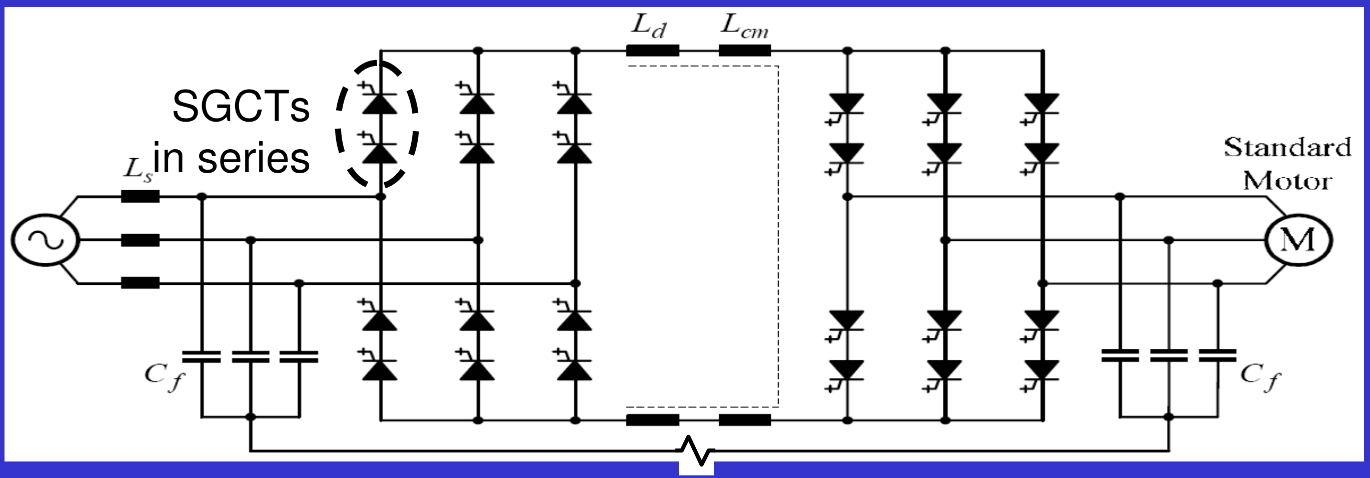
Simple topology

Durable design – fault tolerant

Line reactor version required motor insulation suitable to address CMV

Topology Fundamentals – Current Source

CSR+CSI with Common Mode Voltage Elimination



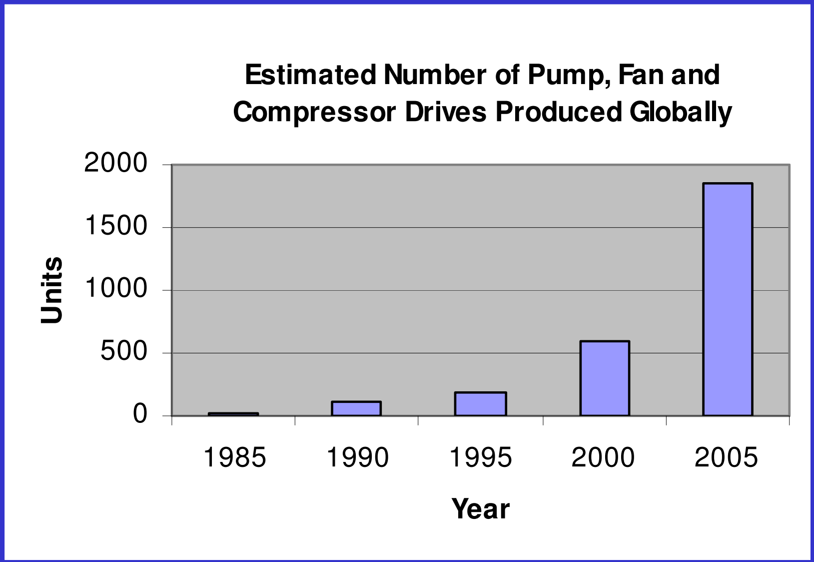
- Introduced in 2000, CMVE addition in 2004
- Does not require an isolation transformer
- Inherent regenerative braking
- Near-sinusoidal output voltage waveform
- Low common mode voltage
- Simple power structure
- Low component count – rectifier same component as inverter
- Virtually unlimited cable distances between drive and motor

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 than the total demand in year 2000 in one facility
- 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
- Standard Features
  - Regenerative braking
  - Communications / Connectivity

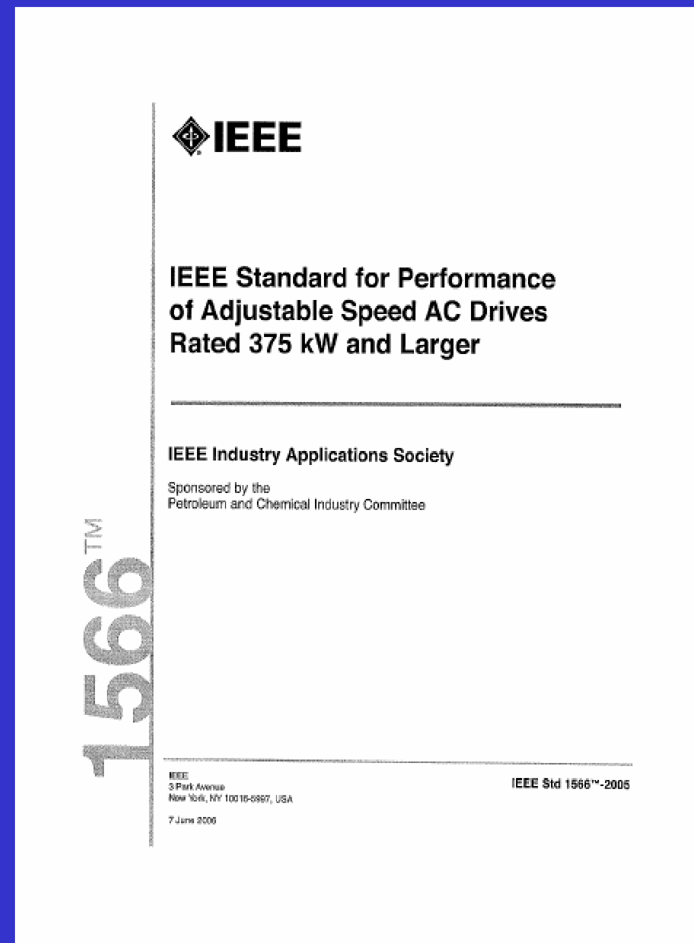
Need for a performance standard

- 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 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

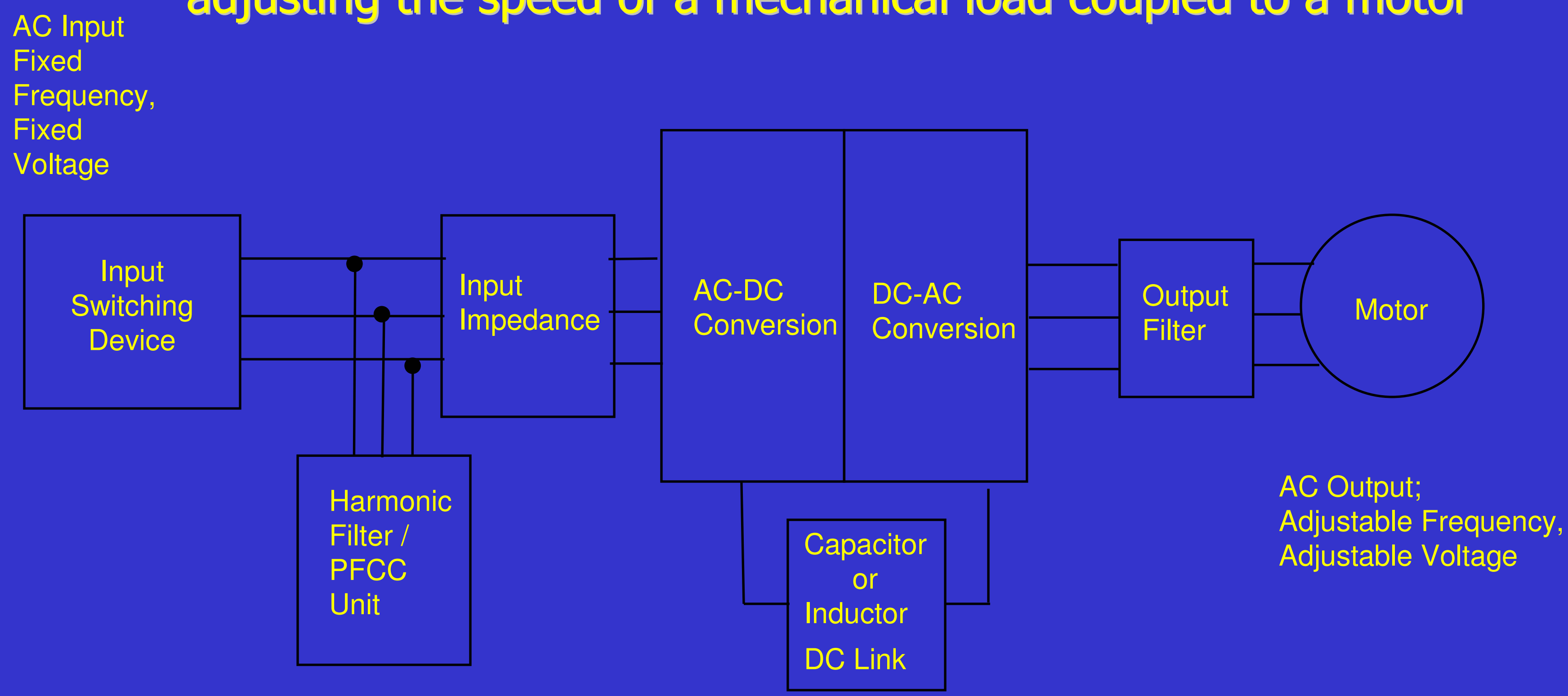
IEEE Std 1566™-2005

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 which have been identified can be achieved immediately

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"



IEEE 1566 Scope

AC Adjustable Speed Drive System

- Safety
- 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

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

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
- 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

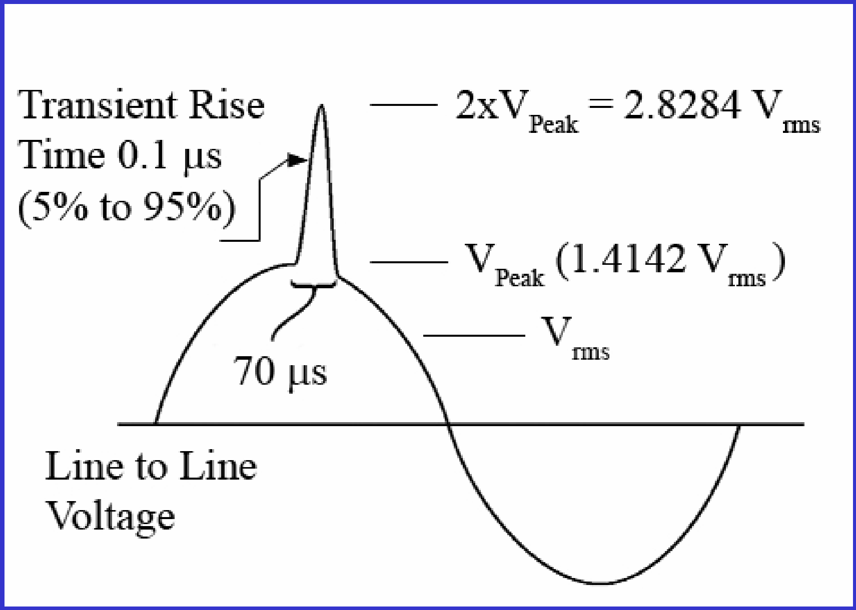
Input Tolerance

- 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

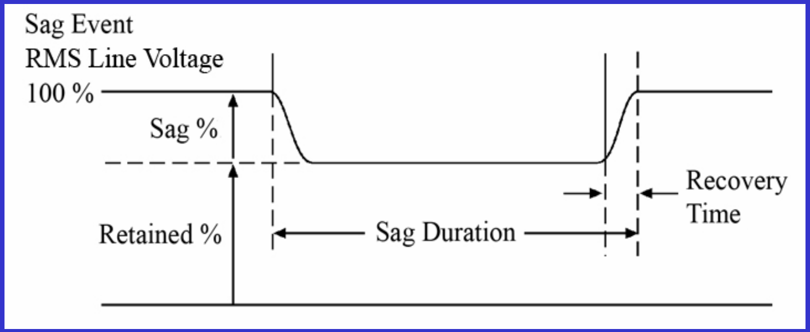
- Input power supply over-voltage transients of 2.8 times the nominal rms
- Rise time of 0.1 µs
- Base width of 70 µs



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



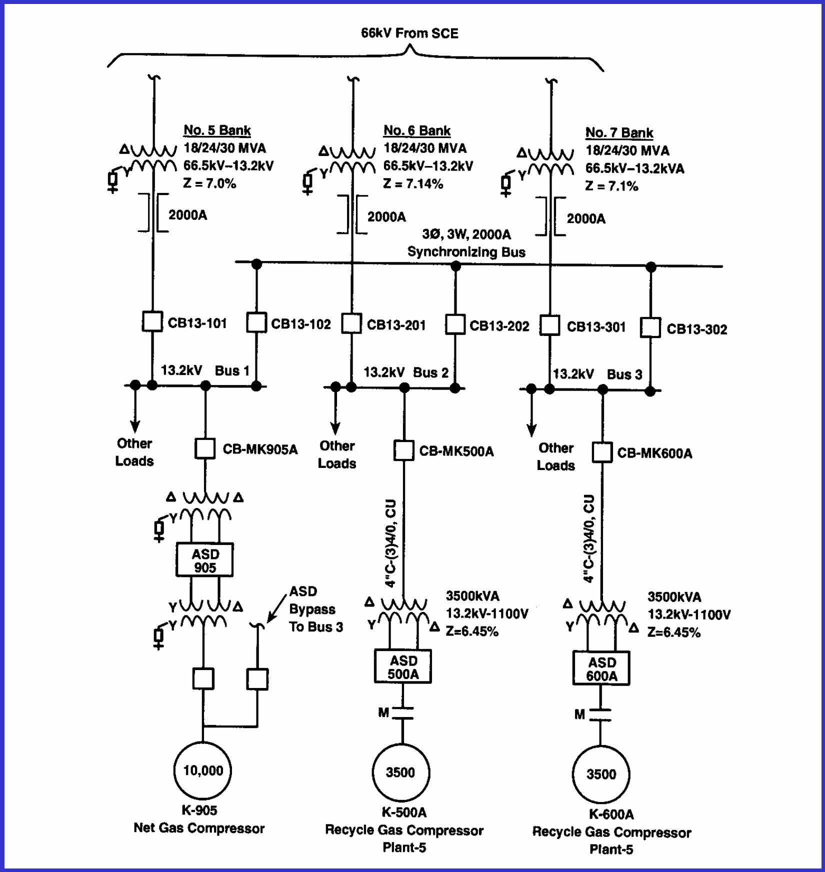
Harmonics and noise immunity

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

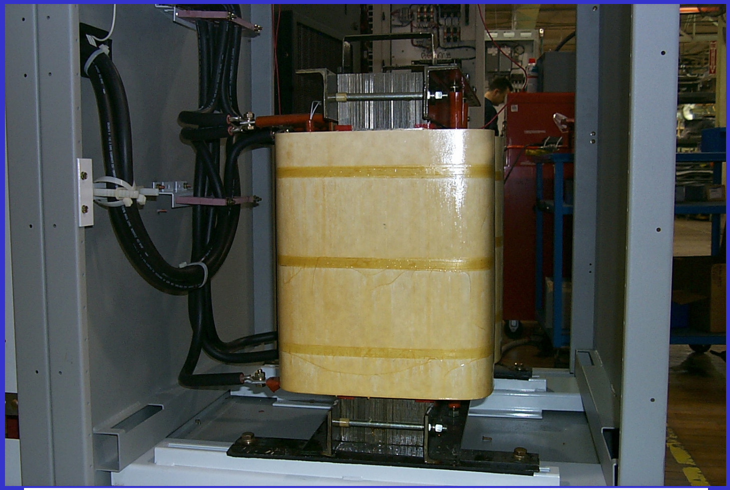
- Various control and communication options
- Defines requirements for local/ remote operation
- Alarm and fault diagnostics, first out report sequence
- Non volatile alarm and shutdown data
- Trending and troubleshooting requirements
- All data available on digital link
- Include all required software 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

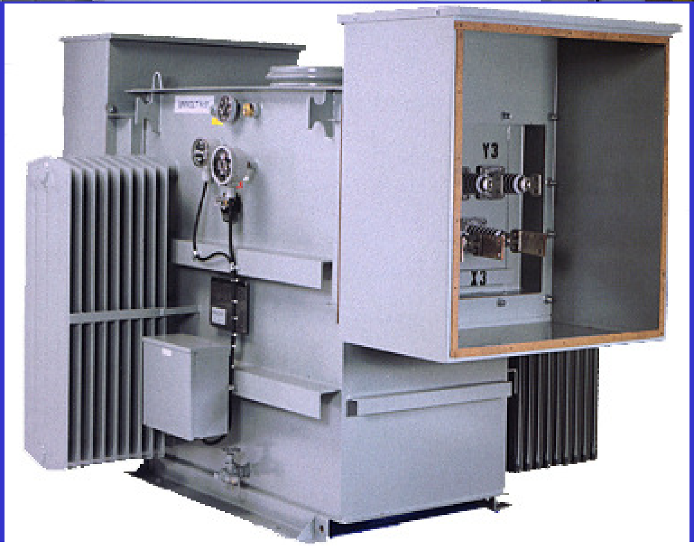
Bypass Operation

- 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.

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)
- Effect of harmonics, voltage stresses – long motor life
- Consider effect of reduced cooling at lower operating speeds
- Synchronous machines field excitation
- Retrofit criteria

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

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

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

Annexes

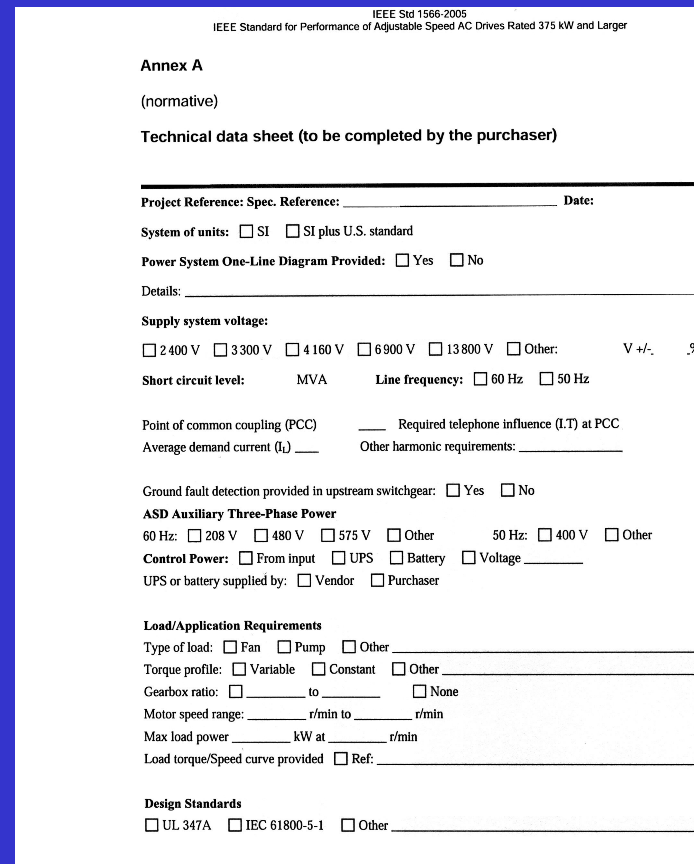
Annex A – Purchaser Data Sheet

Annex B – Manufacturer Data Sheet

Annex C & D - Informative

- Engineering Studies - C
- Bibliography - D

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 ______________________

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
  - Input to the standard