

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



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**IEEE Southern Alberta Section
PES/IAS Joint Chapter Technical Seminar**



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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).

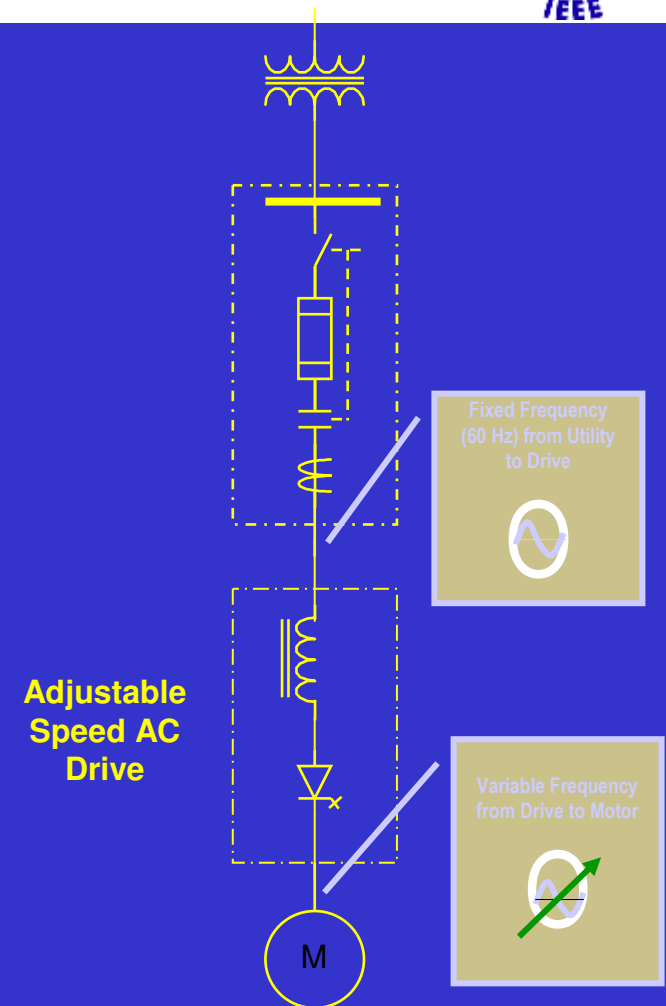
$$\text{MOTOR SPEED} = \frac{120 \times F}{P}$$

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”

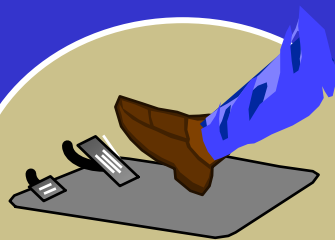


What is a “Drive”?

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



Power Conversion



Control Element



Power Source





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

$$\text{RPM} = 120 \times f / P$$

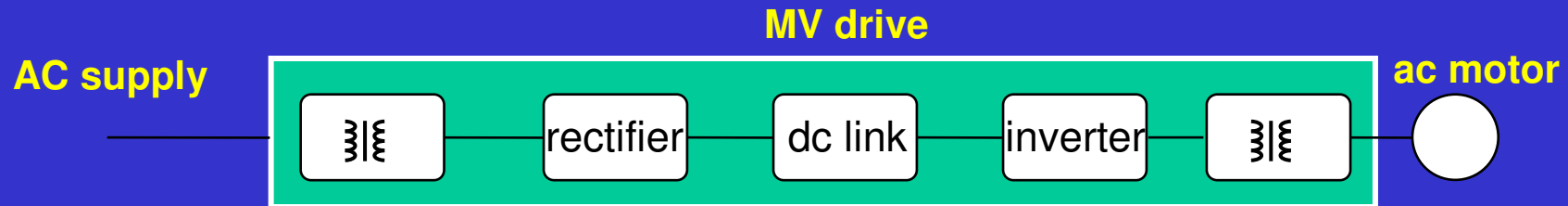
RPM = revolutions per minute

f = frequency of the stator current in Hz

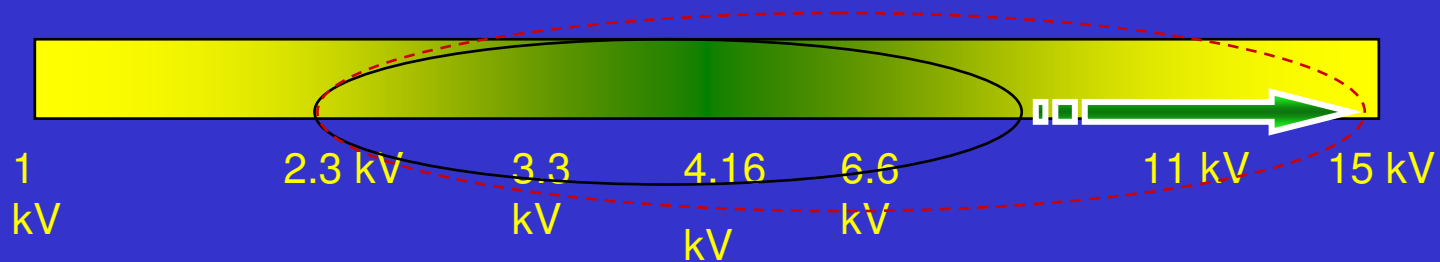
P = number of motor magnetic poles



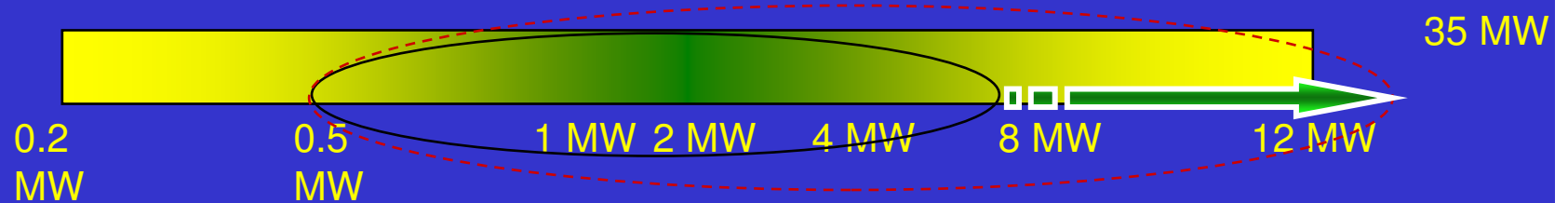
AC ASD Medium Voltage Drives



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



Forest Products

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



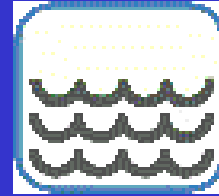
Mining & Metals

- Slurry pumps
- Ventilation fans
- Descaling pumps
- Conveyors
- Cyclone feed pumps



Commercial

- Airport Cogeneration
- Hospital Cogeneration
- University Cogeneration
- OEM Chillers/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

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

Water / Waste Water

- Raw sewage pumps
- Bio-roughing tower pumps
- Treatment pumps
- Freshwater pumps

Electric Power

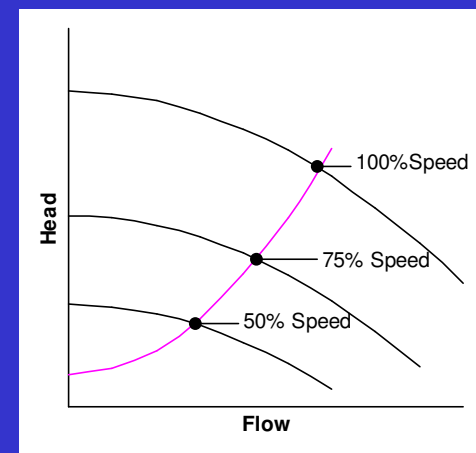
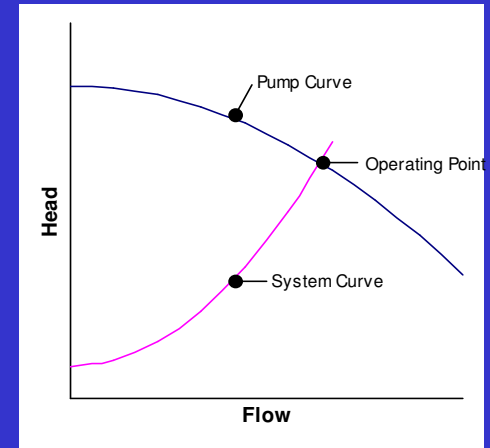
- Feed water pumps
- Induced draft fans
- Forced draft fans
- Effluent pumps
- Compressors



AC Induction Motor Operation with ASD Pump Example

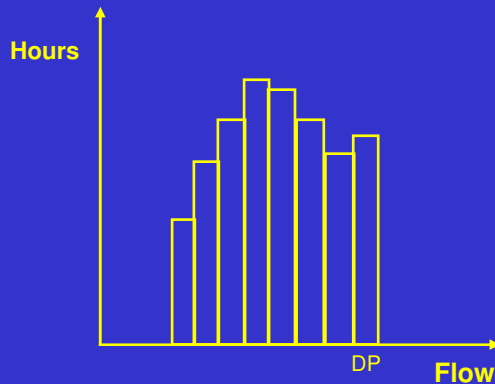


- All pumps must be sized to meet maximum flow and the static & dynamic heads of the system – “System Curve”
- Pump is selected such that the “Pump Curve” intersection with the System Curve gives the desired “Operating Point”
- Adjustable speed operation allows flow to be controlled by shifting the operating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

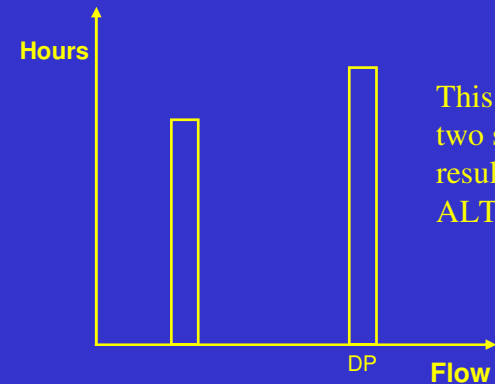




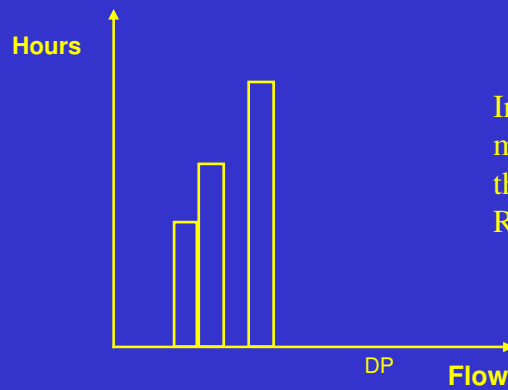
Energy Savings Considerations



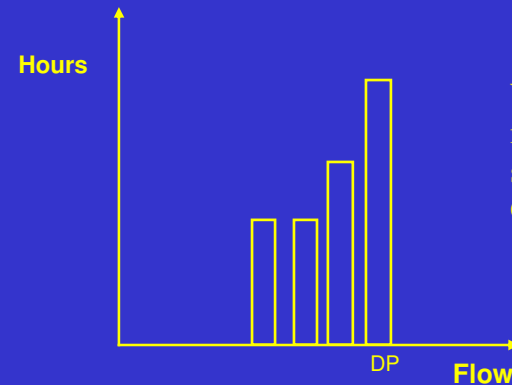
A high Degree of Variability
will typically result in significant
Energy Savings
GOOD CANDIDATE



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

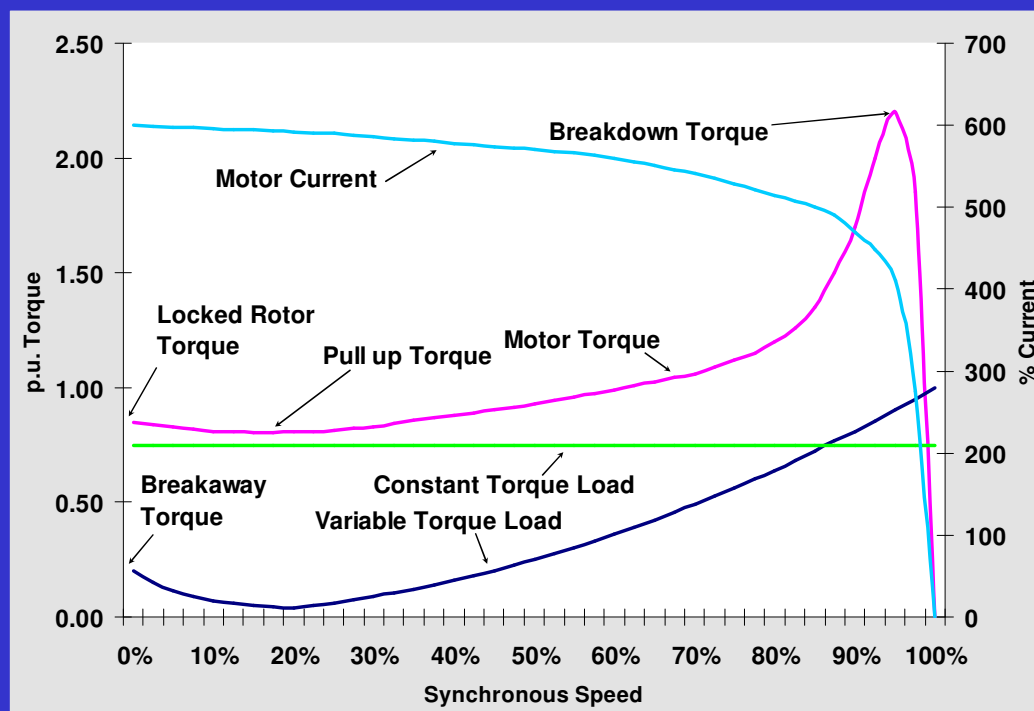


Typical Induction Motor Performance

- 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

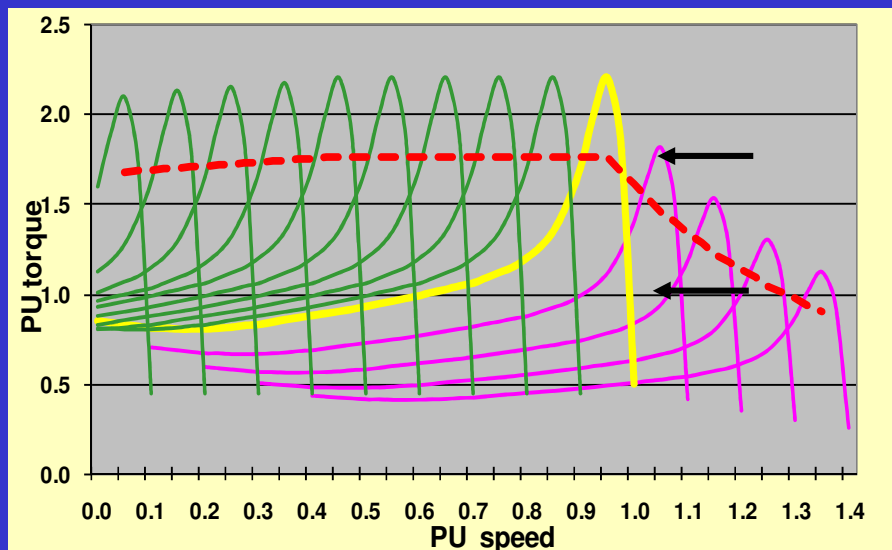




AC Induction Motor Operation with Adjustable Speed Drive

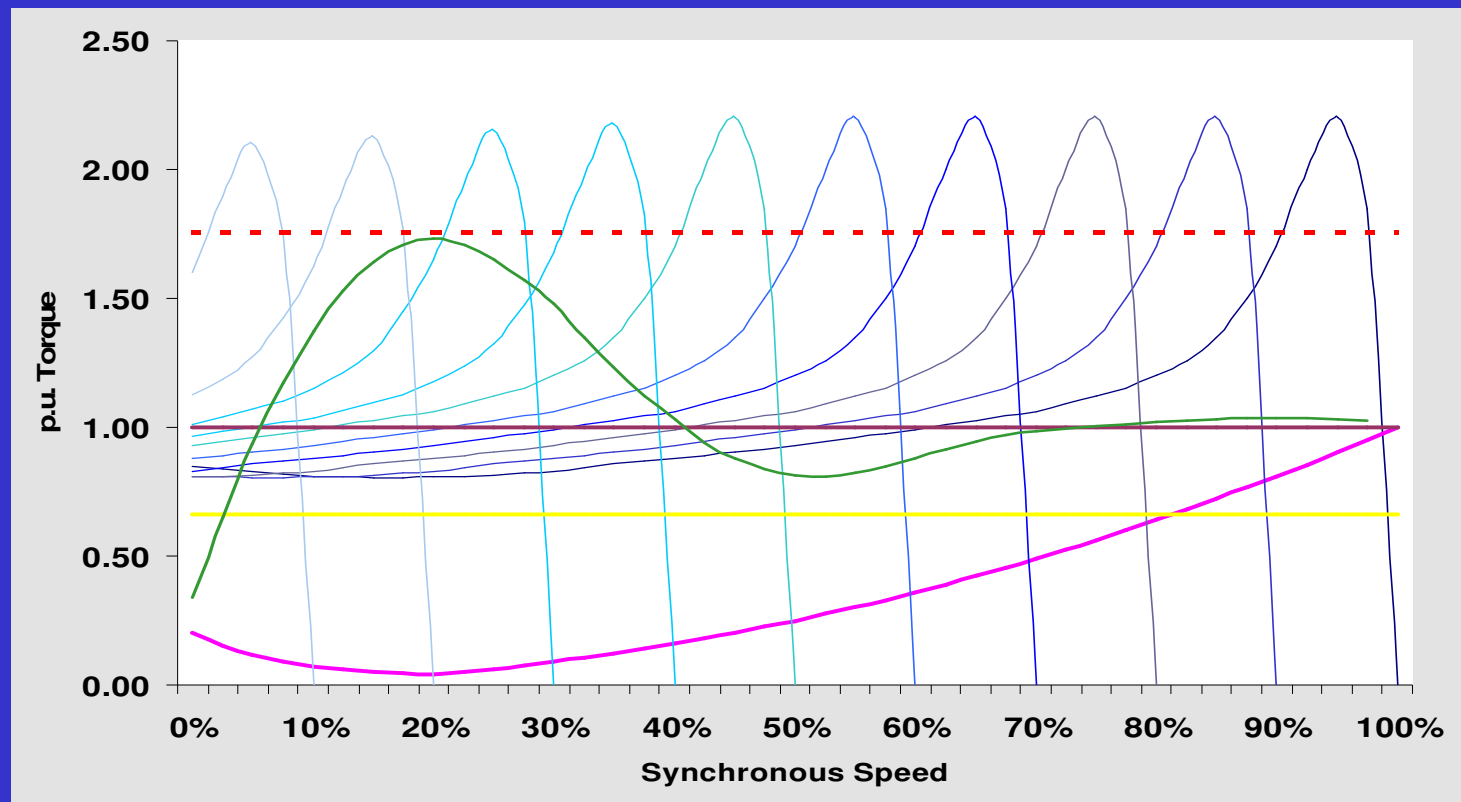


- Allows continuous operation at reduced speeds by altering output frequency to motor
- Improves motor operating characteristics beyond across the line starting – torque / current
- Motor operates on right side of breakdown on torque curve
- Starts are not limited as on across the line start
- Torque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





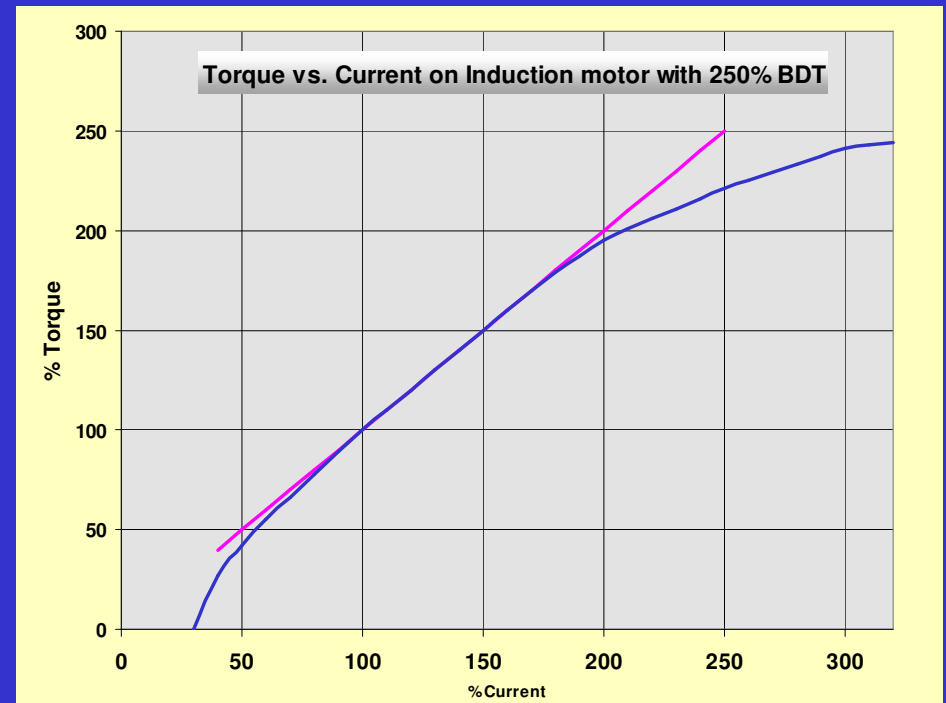
Motor & Load Torque Evaluation





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

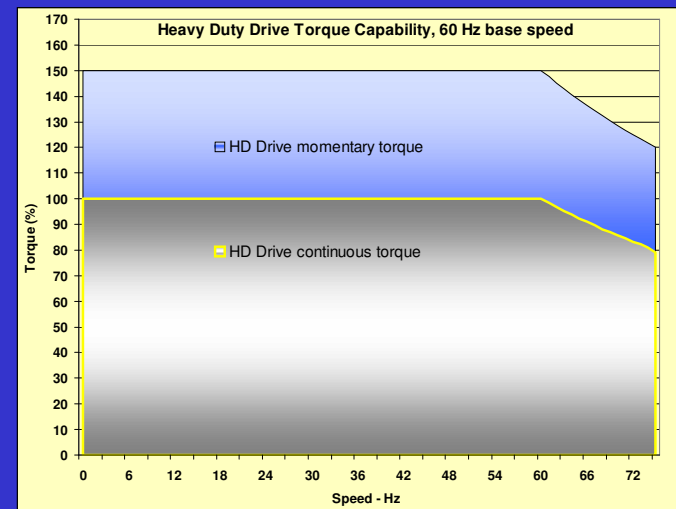
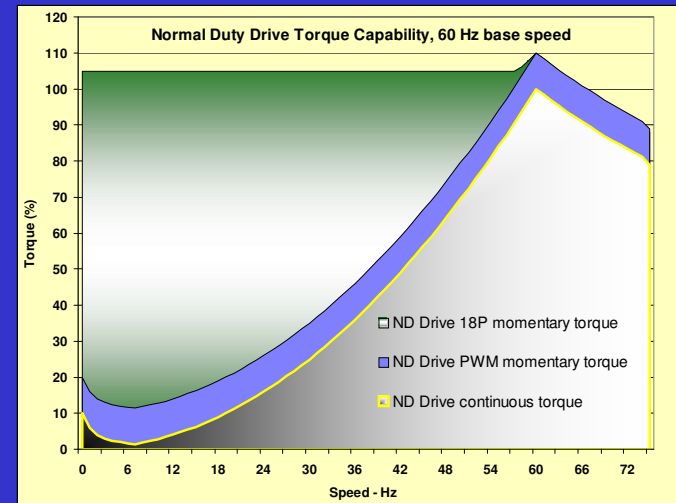
Load Profile is the prime consideration when sizing an ASD

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



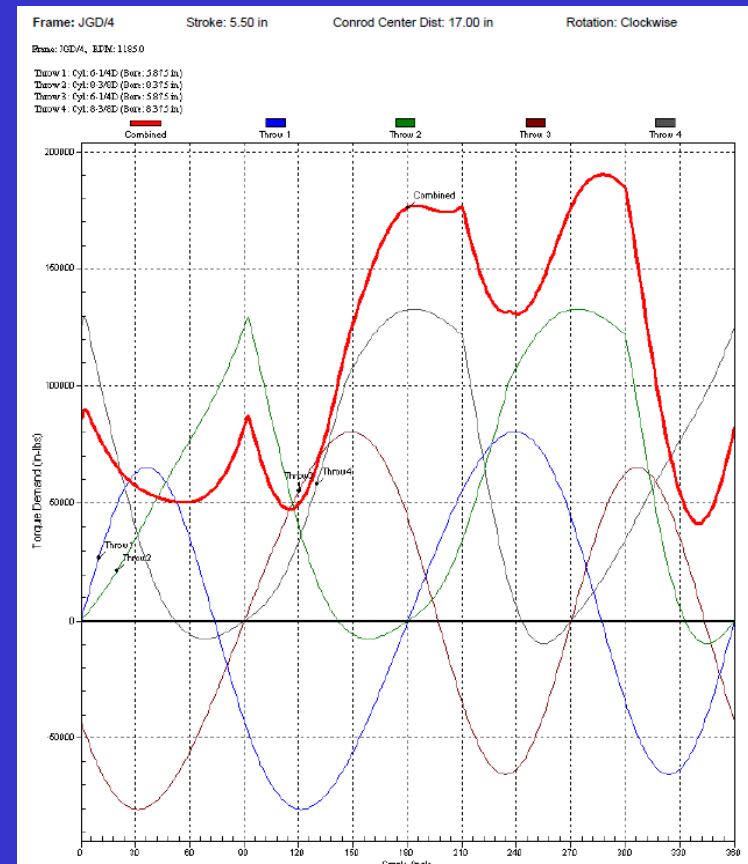


Reciprocating Compressors



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

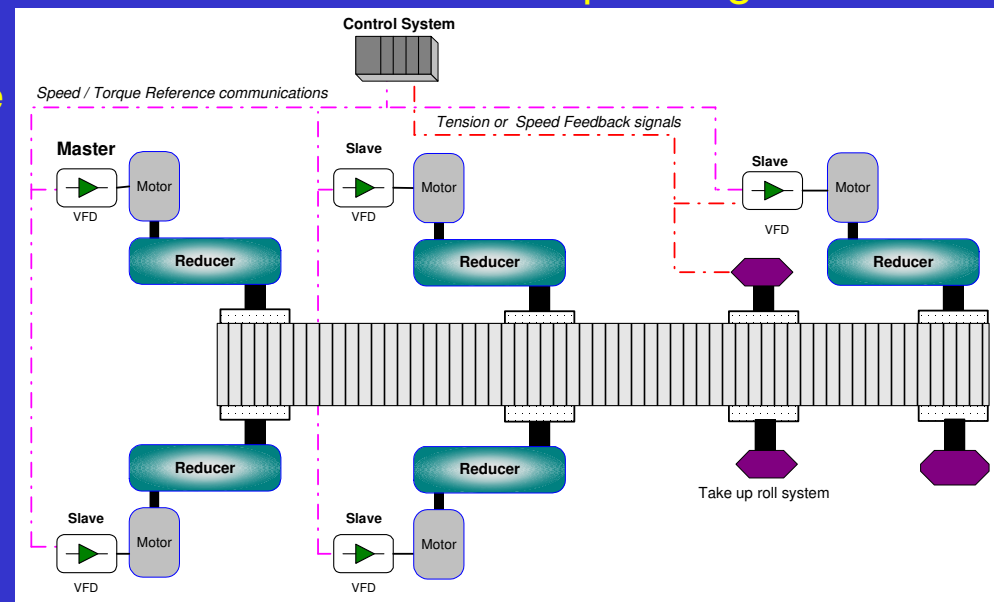
Higher / custom starting torques can be accommodated

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

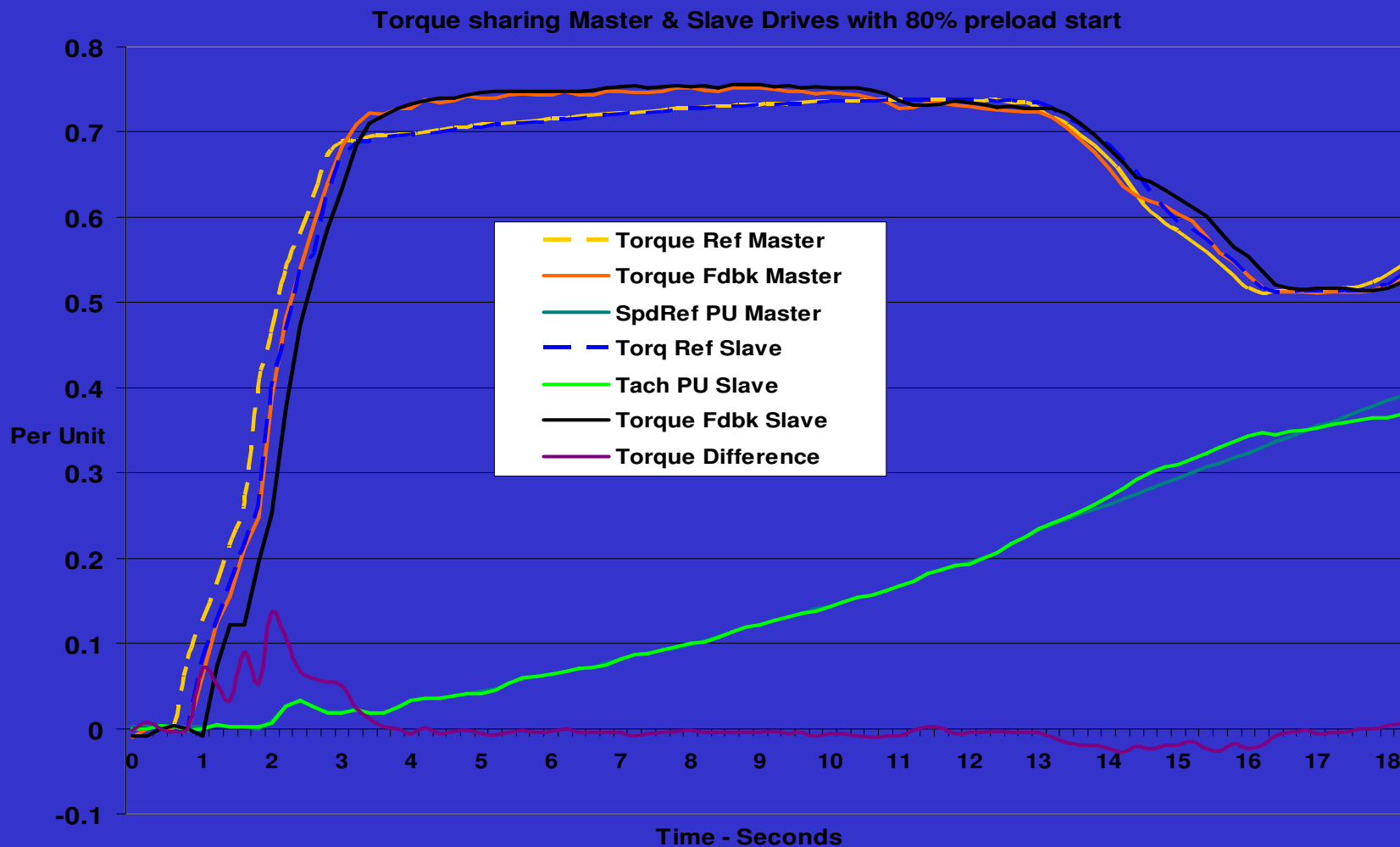
Affected parameters

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





Load Sharing

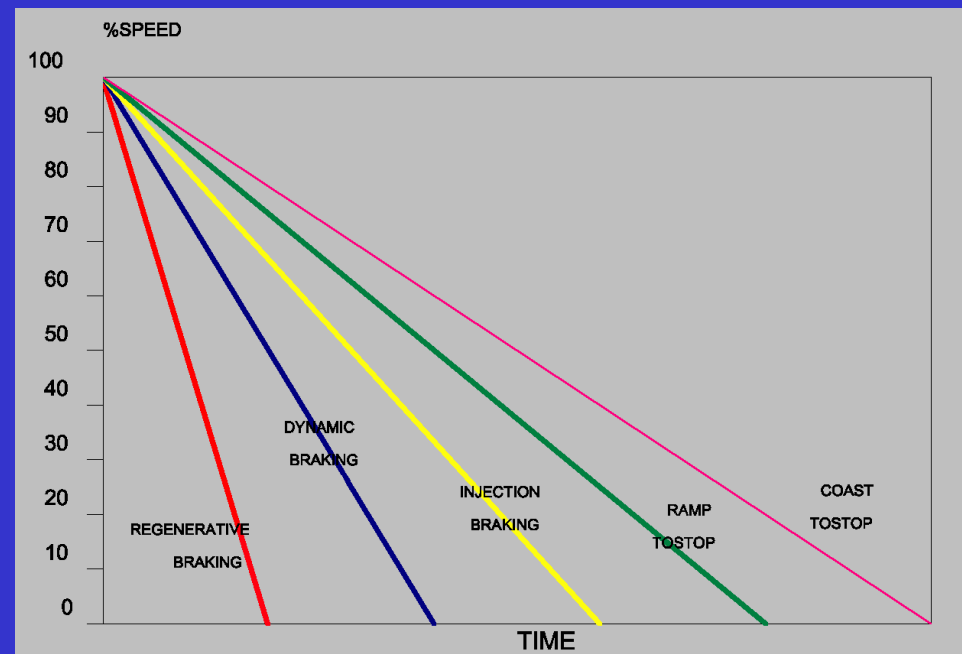
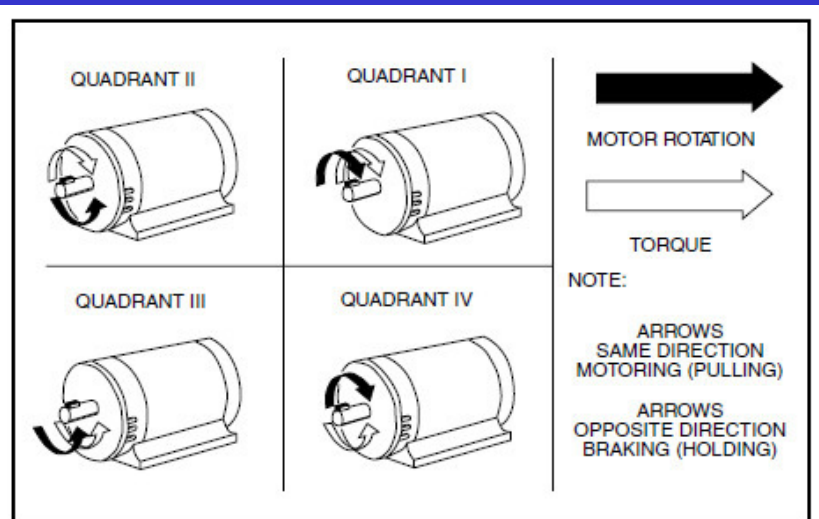




Regenerative Braking

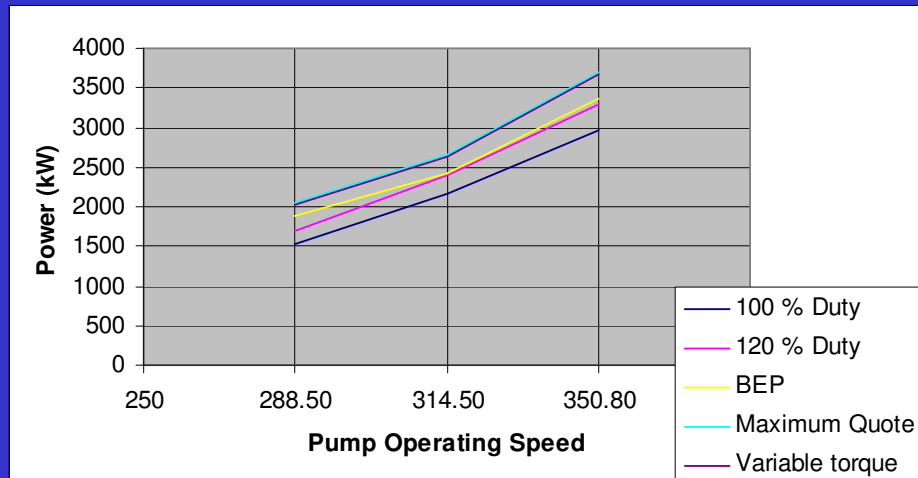
Overhauling loads are the most demanding braking application. Braking energy equal to or even possibly exceeding the motoring requirement are possible in applications such as conveyors, slurry pumps, etc. Regenerative Braking is the best method to deal with this.

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





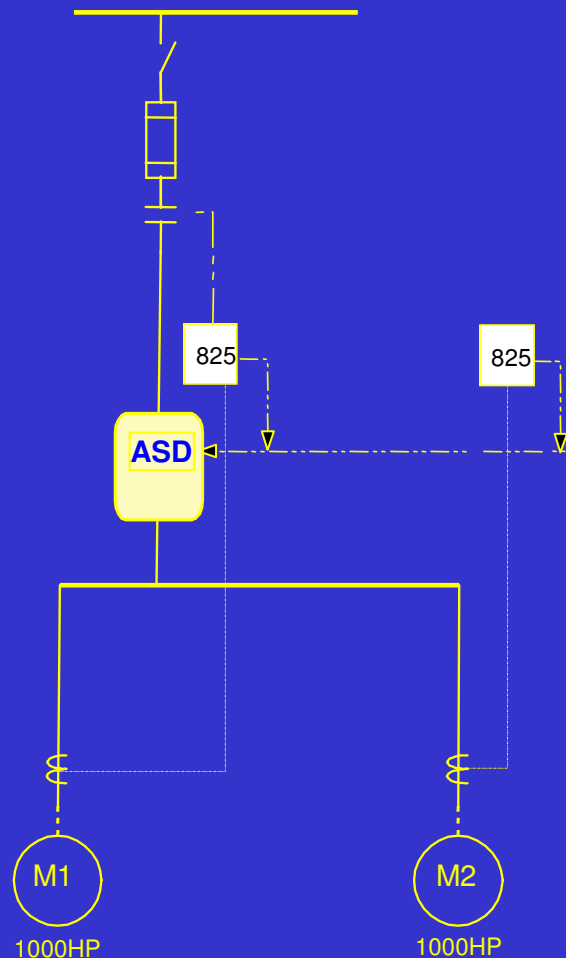
Slurry Pumping / Hydro-transport



- 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

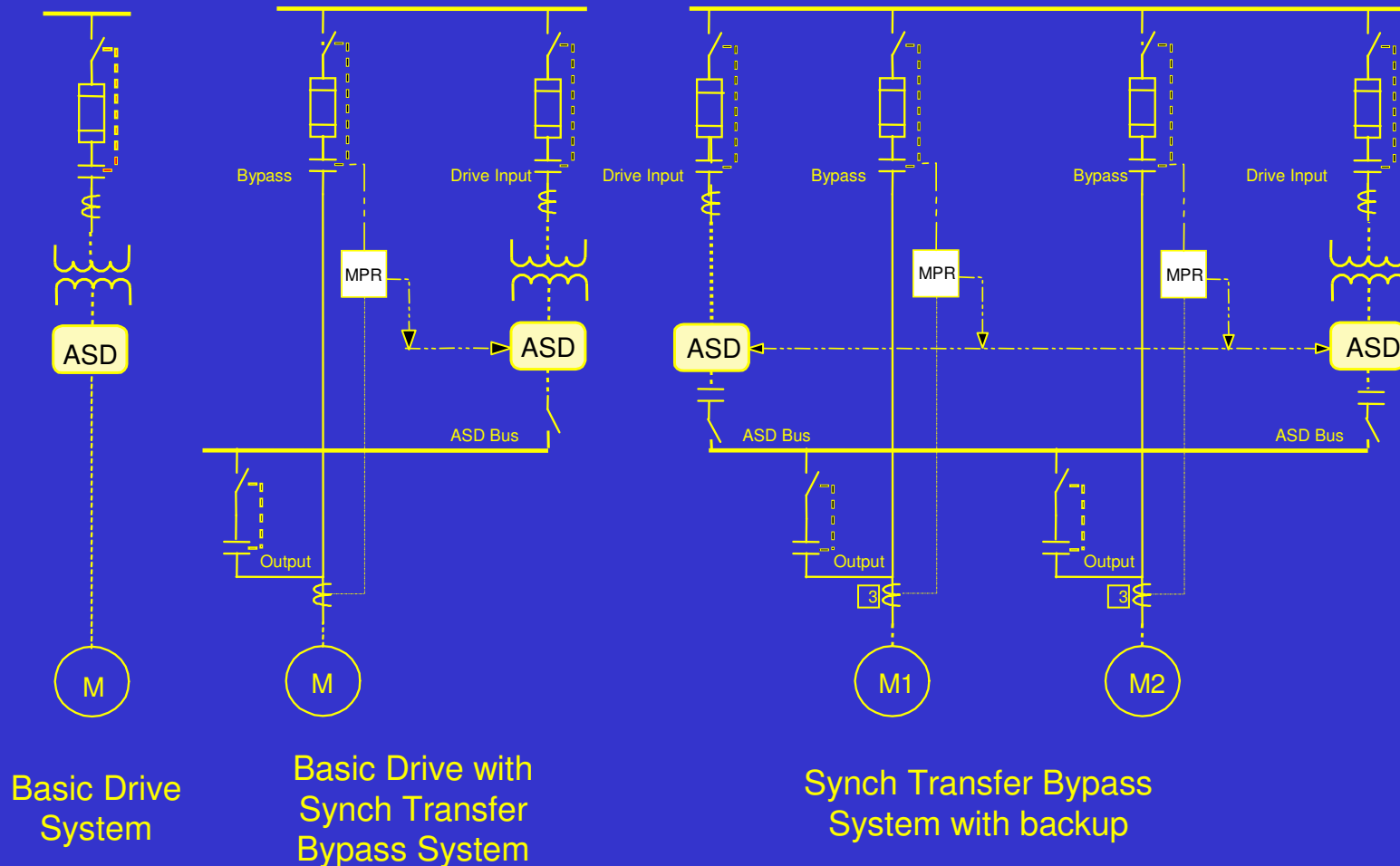
- Mechanically coupled motors must have identical motor characteristics

Individual motor protection required

Can use output contactors to provide or facilitate possible redundancy



Synchronizing Transfer Configurations





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

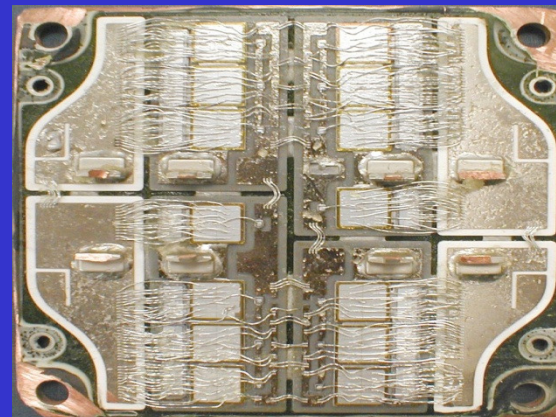
Cost Effective

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



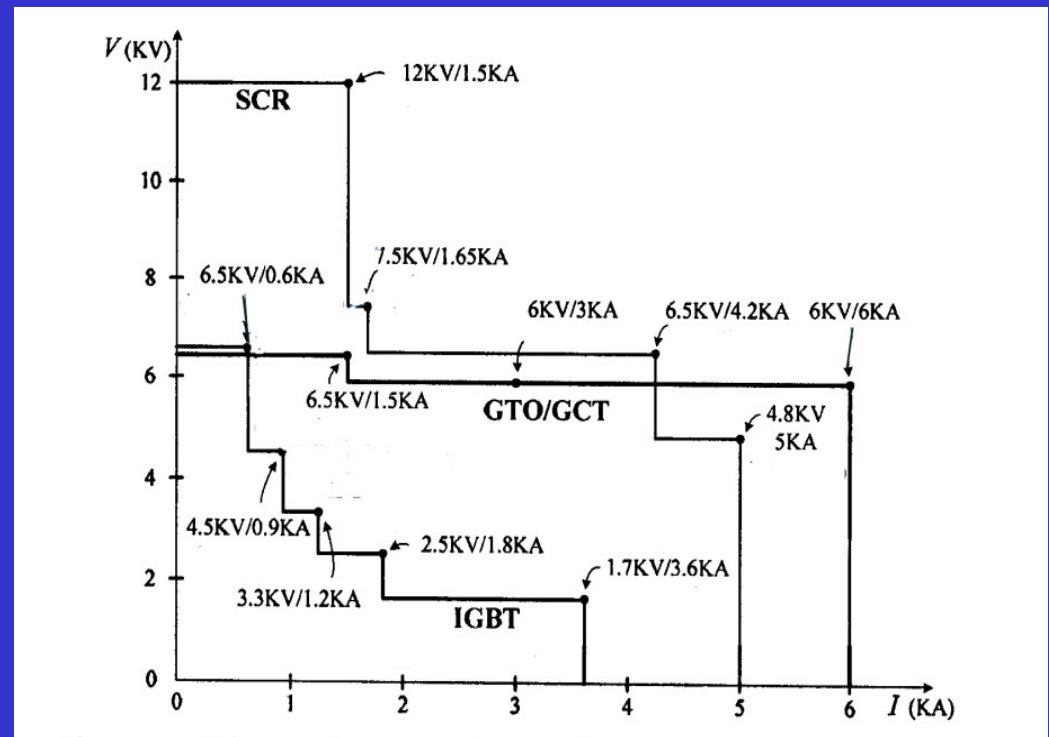


Semiconductors



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)

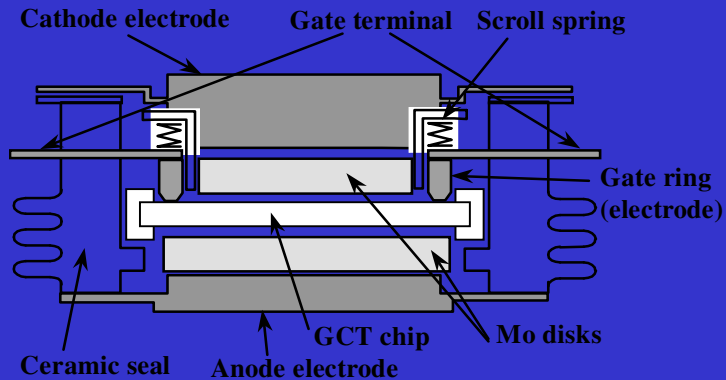
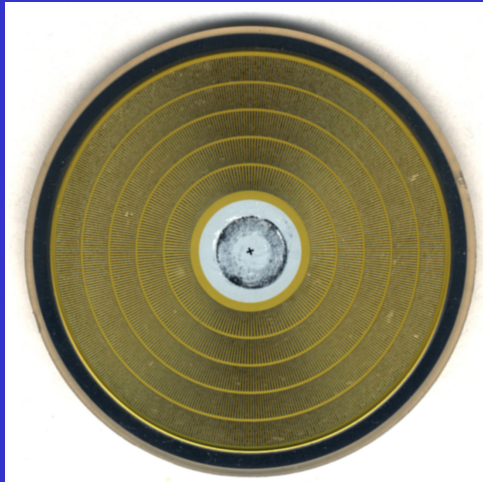
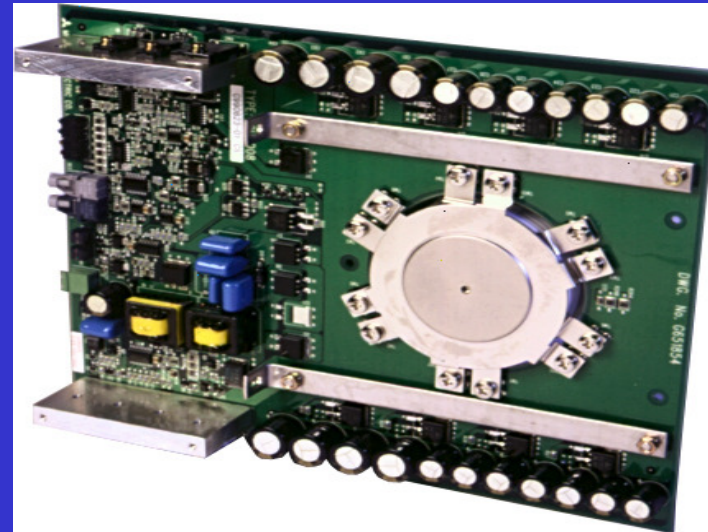


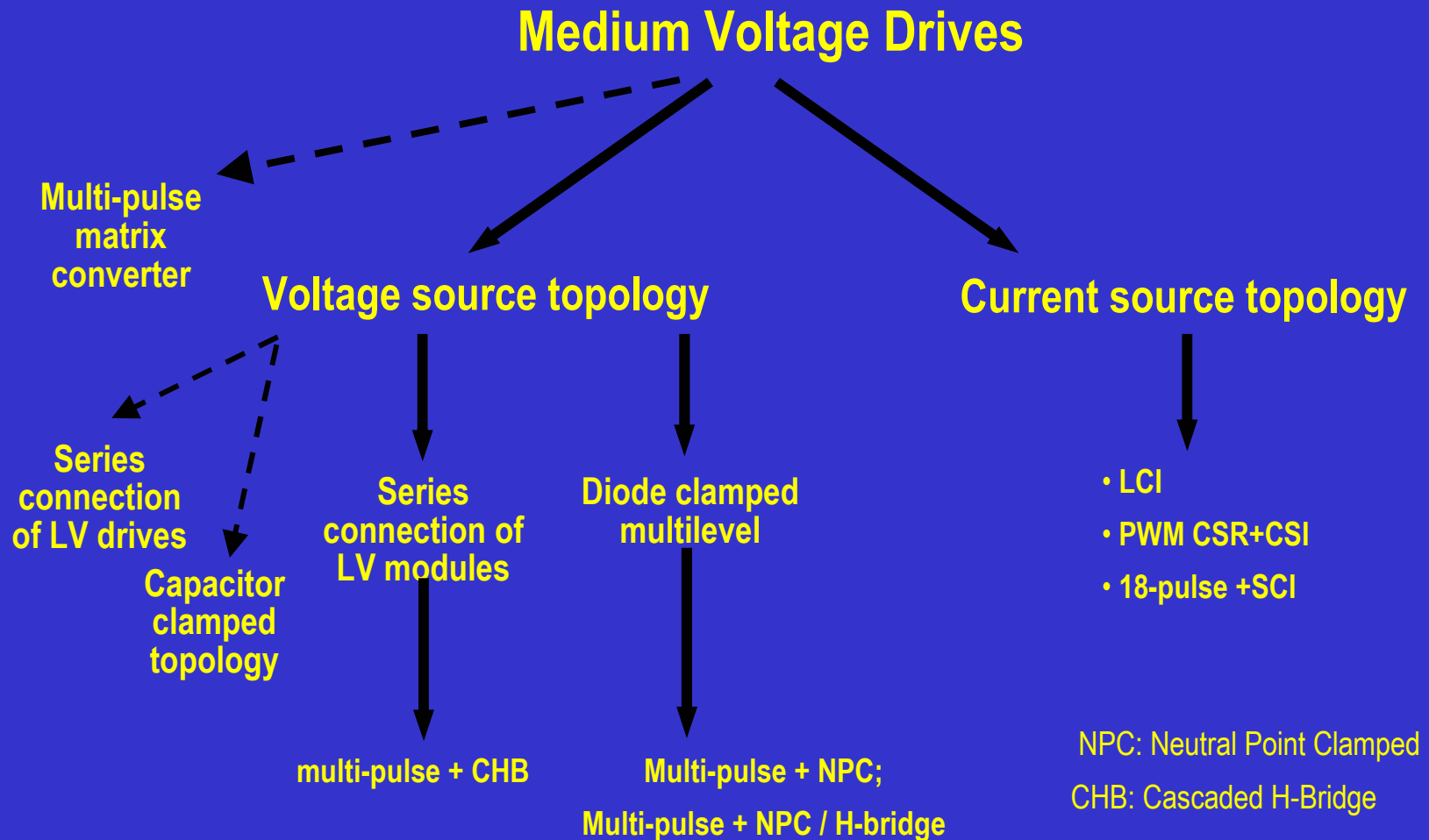
Fig. 4. Cross-sectional structure of SGCT.



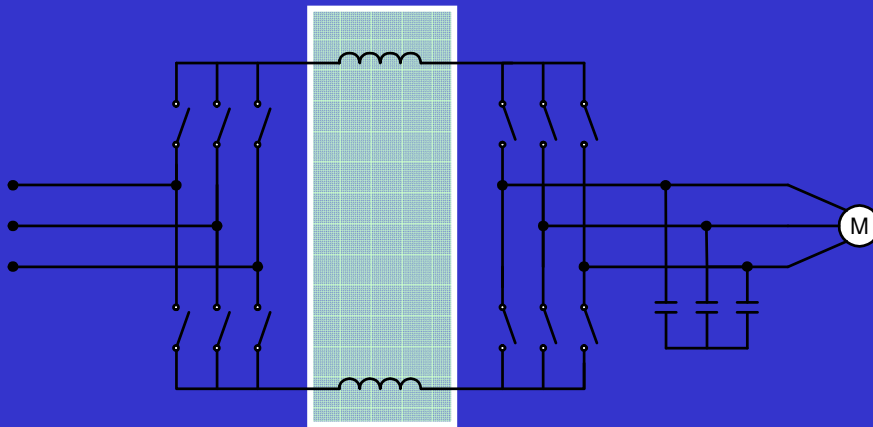
Device is utilized at half of the rated design - 50 % margin
Devices can be used in series
Dual Sided Cooling
Superior Thermal Management to the internal wafer
IGCT similar to SGCT except blocks in one direction only



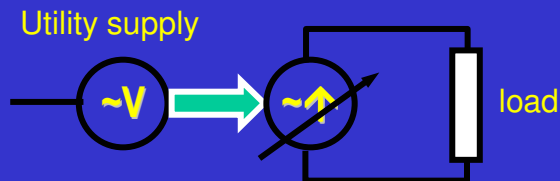
Topology fundamentals: classification



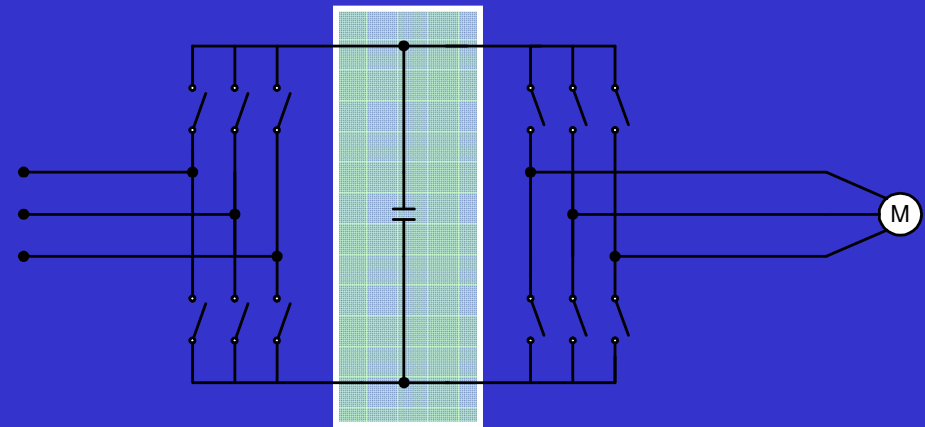
Topology fundamentals: CSI & VSI



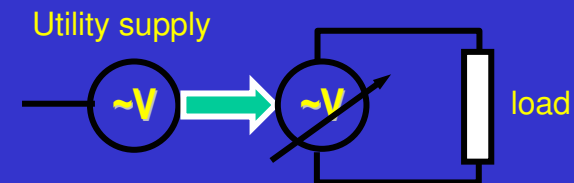
Current Source Topology



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



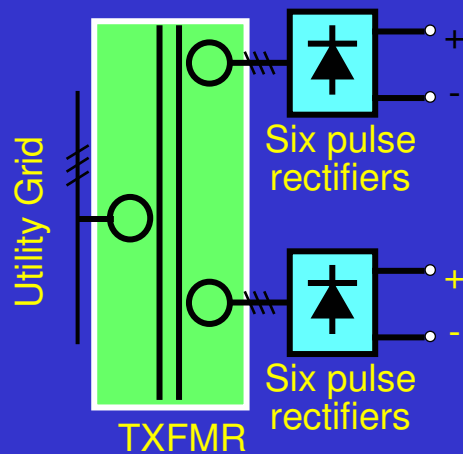
Passive Front End

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

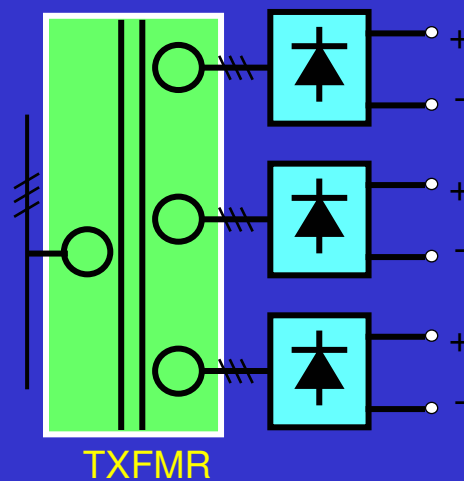
Active Front End

- 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

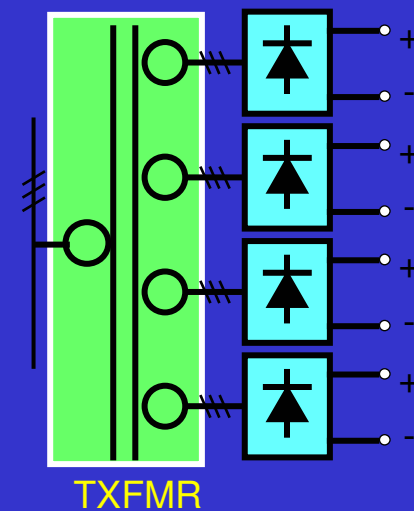
Topology Fundamentals - Rectifier



(a) 12-pulse rectifier
 $\delta = 30^\circ$



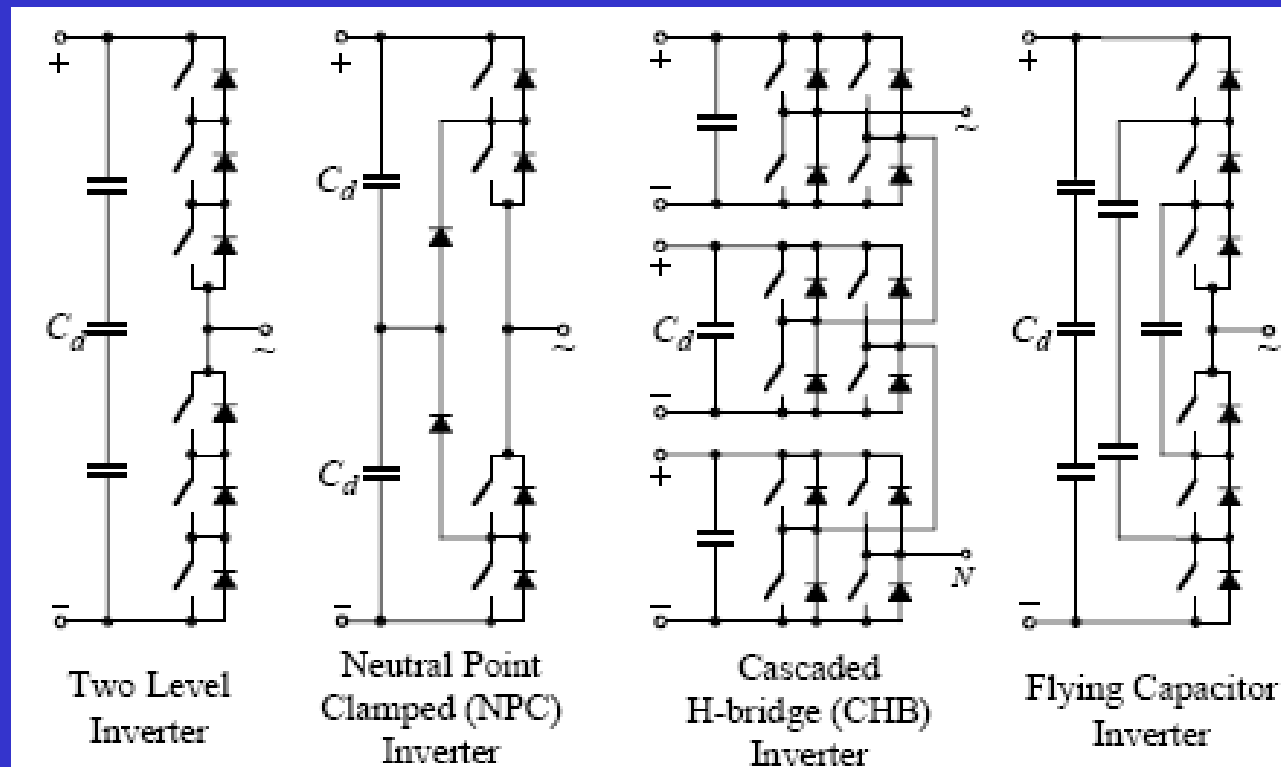
(b) 18-pulse rectifier
 $\delta = 20^\circ$



(c) 24-pulse rectifier
 $\delta = 15^\circ$

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)

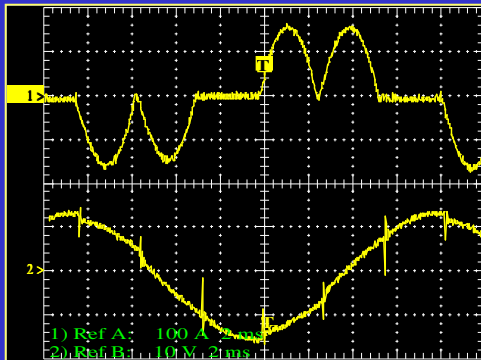
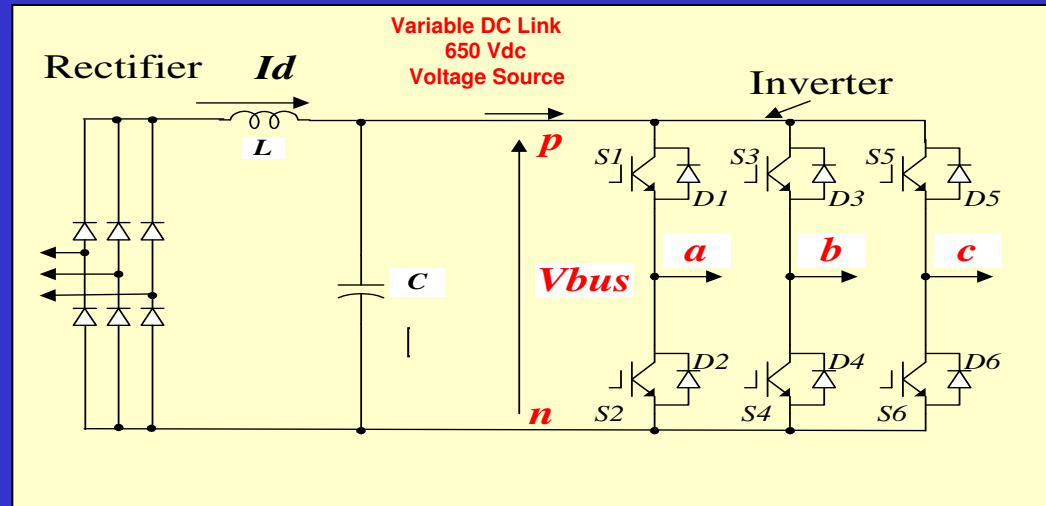
Multilevel Voltage Source Inverter (MVSI)

Multilevel Voltage Source Cascaded H bridge (CHB)

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Topology Fundamentals – Voltage Source Drives



480 Volt Input

Top: Current waveform

Bottom: Voltage waveform

LV VVI 6 Step Base Characteristics

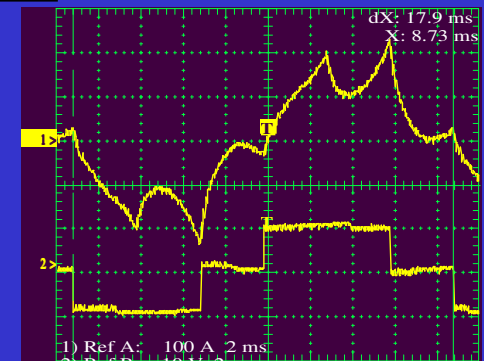
Input:

SCR bridge rectifier

Variable DC Link bus voltage

Output:

Inverter switches to obtain required waveform orientation



480 Volt Output

Top: Current waveform

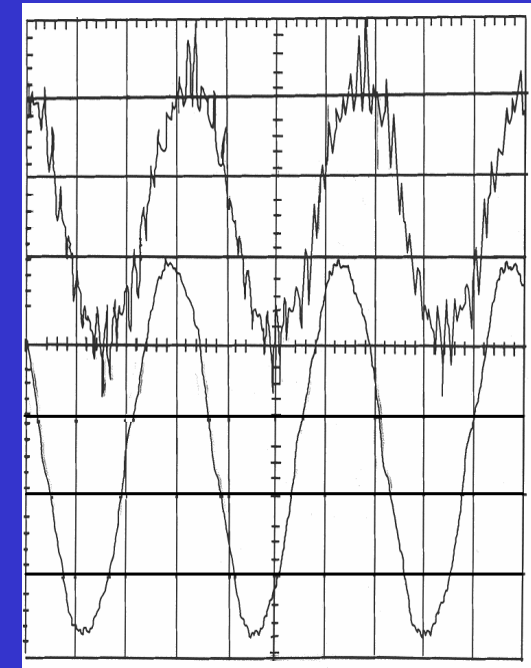
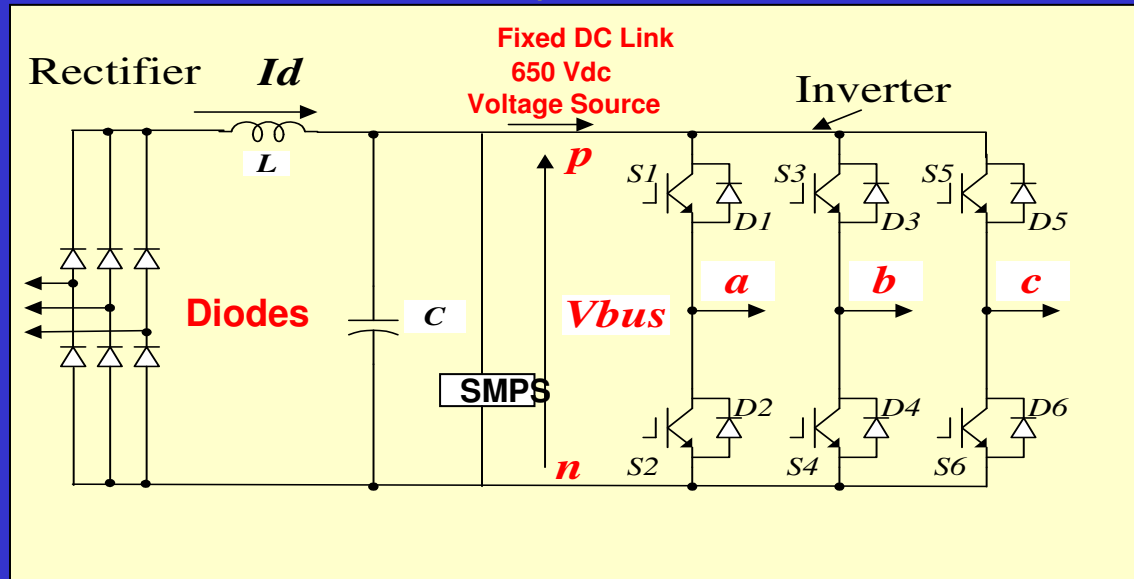
Bottom: Voltage waveform



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:

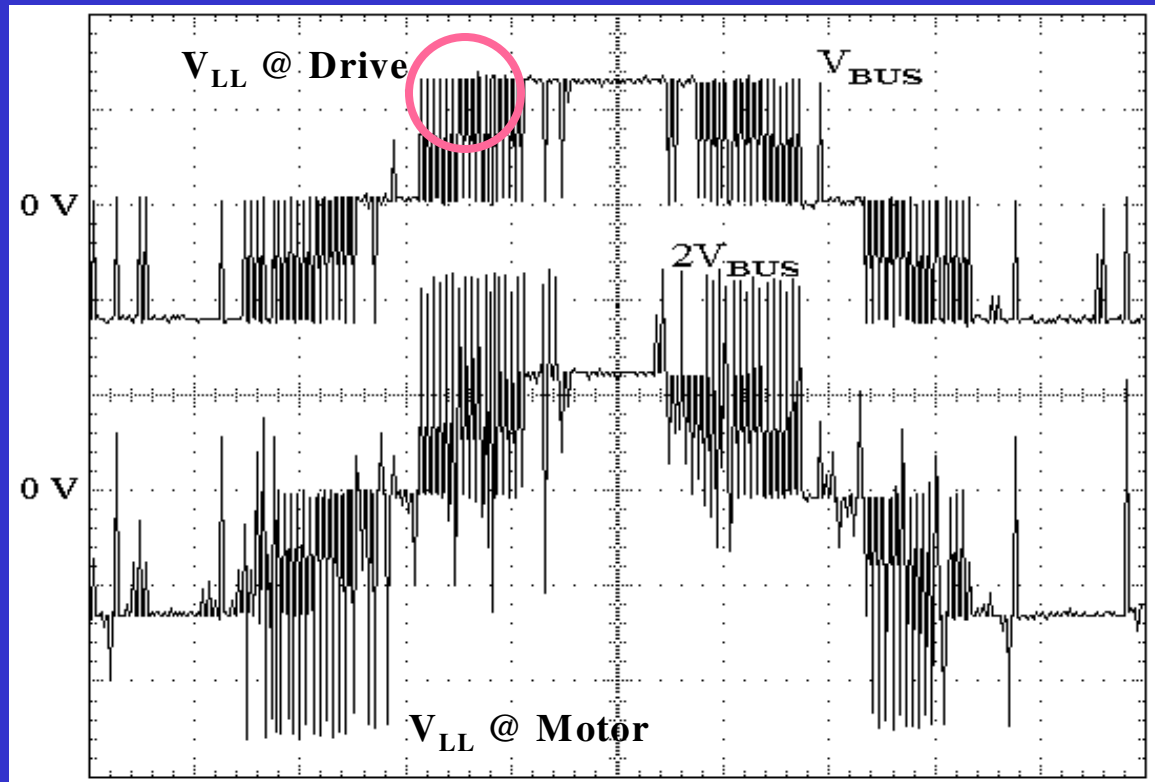
- PWM inverter switches @ high frequencies (2 – 10 kHz) to obtain required output voltage and harmonic elimination
- Most common LV technique employed in industry presently



Transient Peak Over-Voltages at Output

Output
Voltage
@ PWM
Drive

Output
Voltage
@ Motor
with Long
Output
Cables

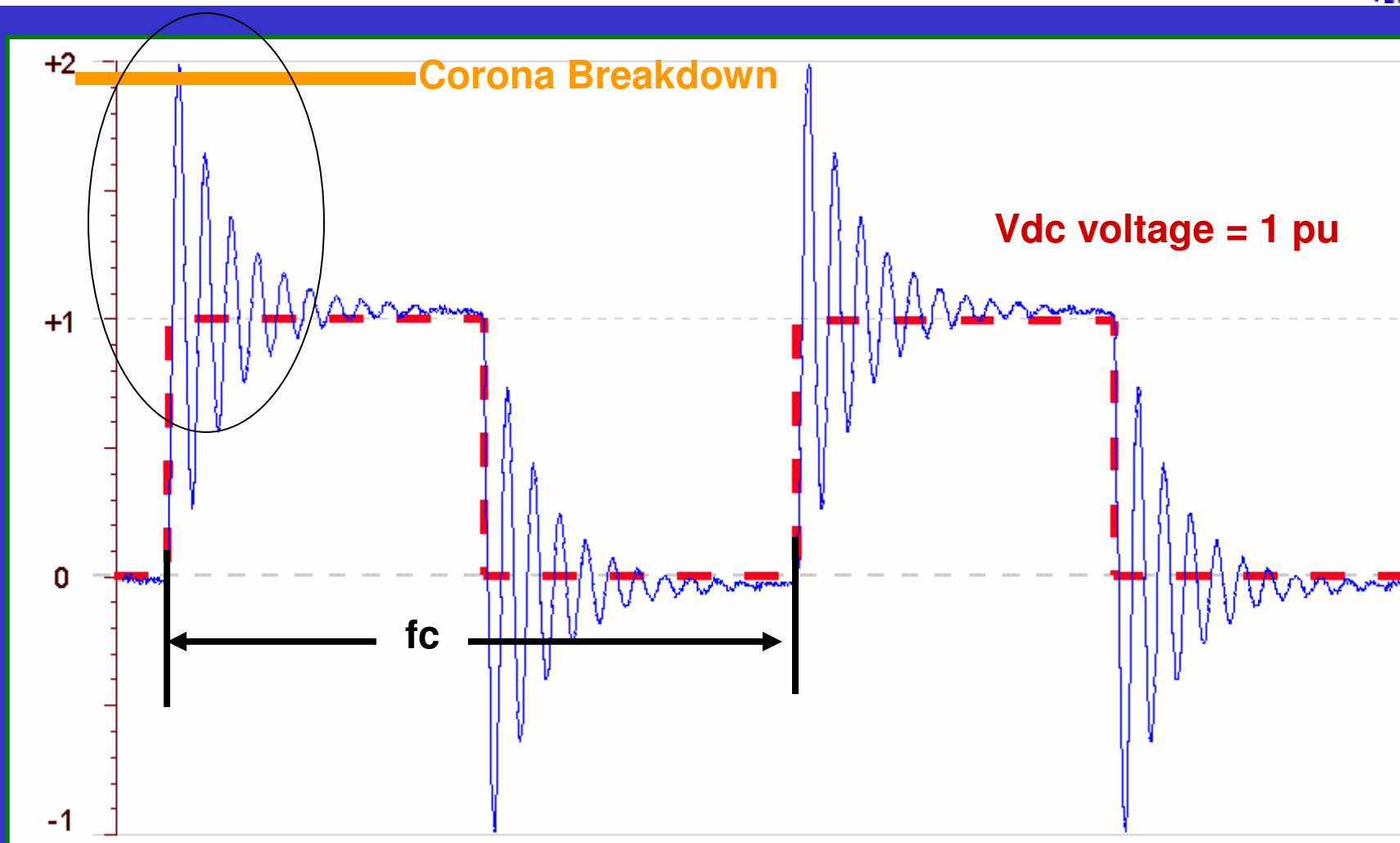


Transient Over-voltages of twice DC bus [2pu] are possible at some cable distance. Commonly known as “Transmission Line Effect”
This is due to surge impedance mismatch between Cable and Motor

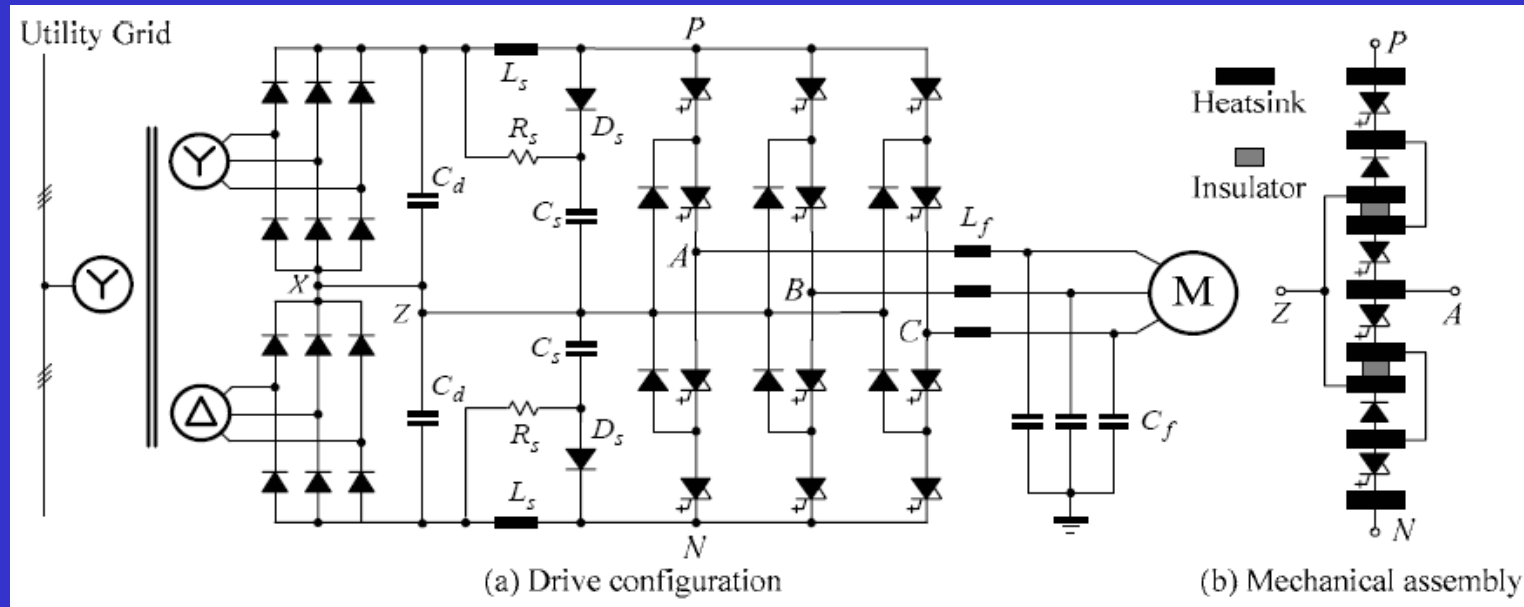
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Output Over-Voltage Transients at the Motor Terminals may Exceed Corona Breakdown Limits of Cable or Motor



Topology Fundamentals – Voltage Source Drives



VSI-PWM 3 Level with Output Filter Topology

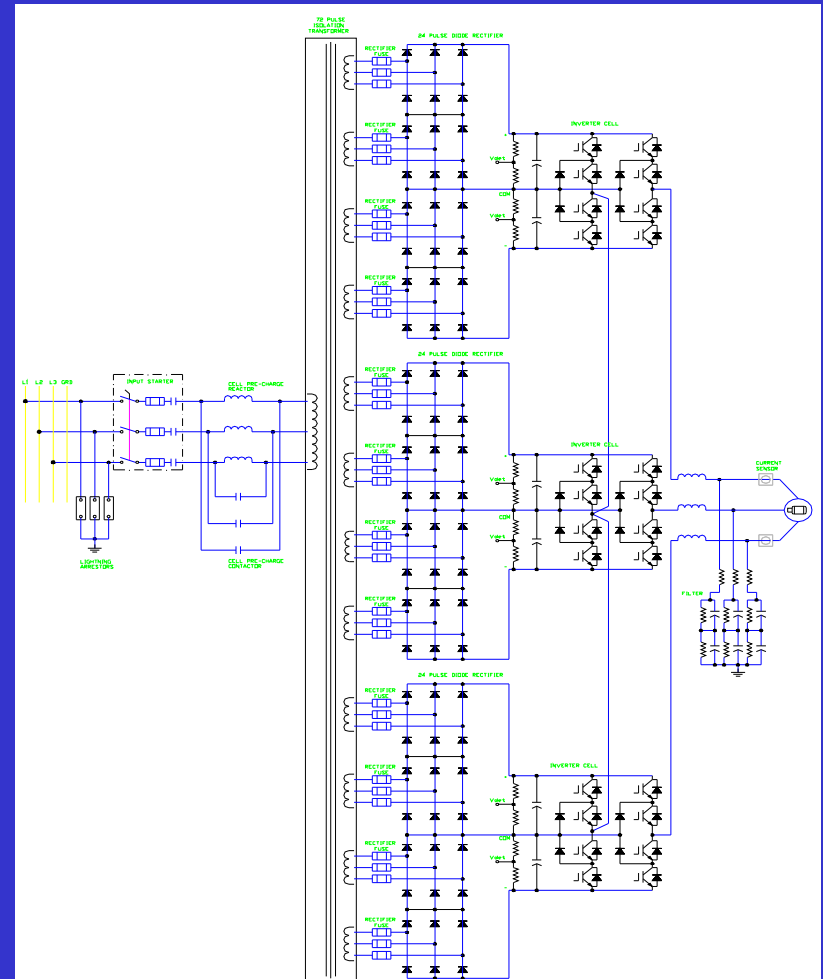
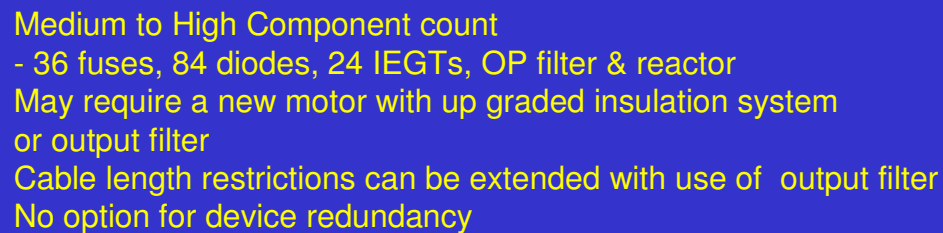
Tuned LC output Filter To reduce Voltage Stress design – motor specific

12 Pulse Rectifier

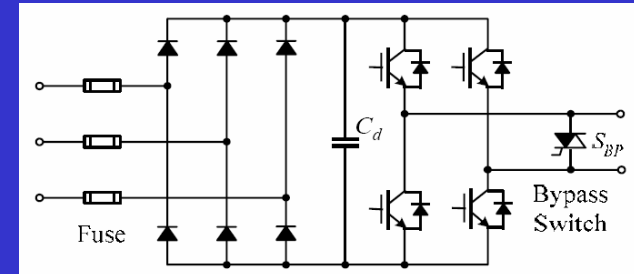
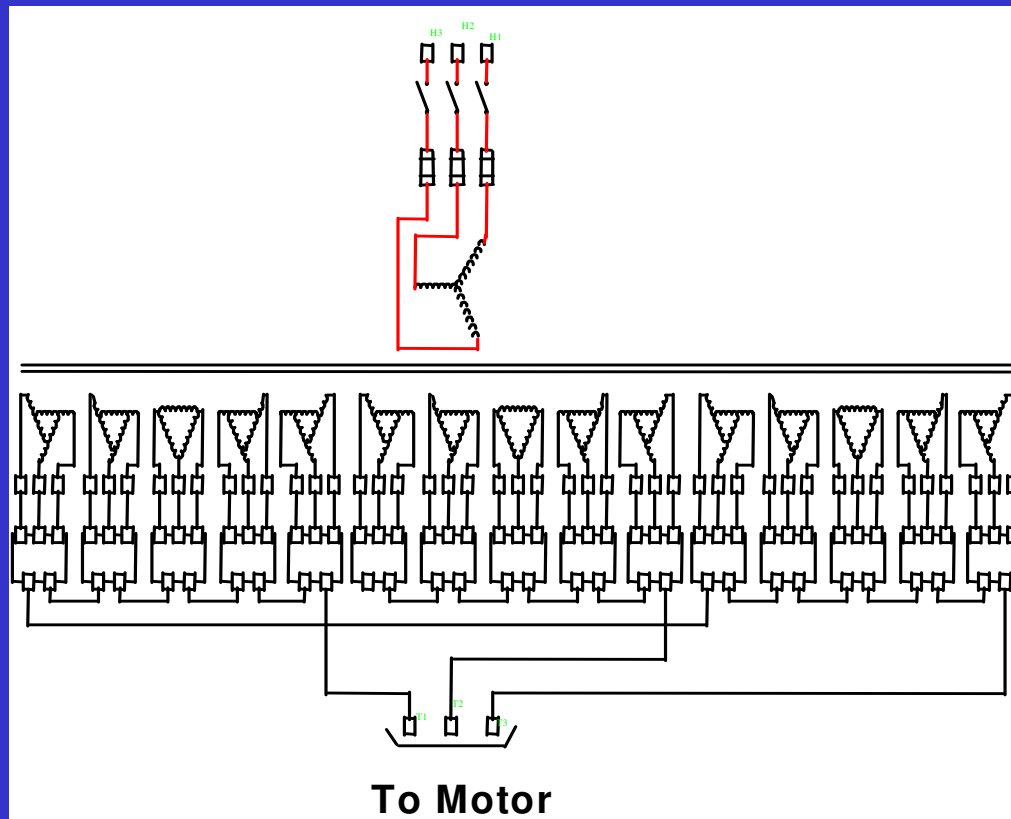
3 Level Neutral Point Clamp Inverter

Medium Component Count

GTO or IGCT Power Devices



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

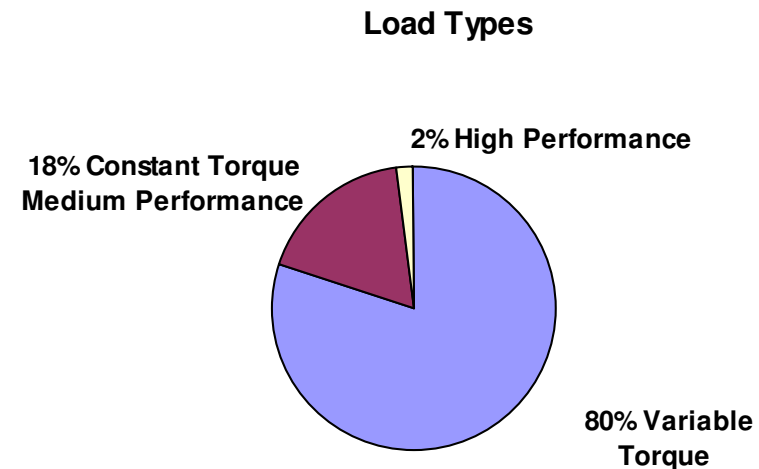
$\begin{matrix} V_{cell} \\ V_{motor} \end{matrix}$	460	630	690	750	1375
2300	3	2		2	
3300	4	3		3	
4160	5	4		3	
4800	6	4		4	2
6600		6	6	5	3
7200		7	6	6	3
10000		9			4
13800					6
14400					6



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

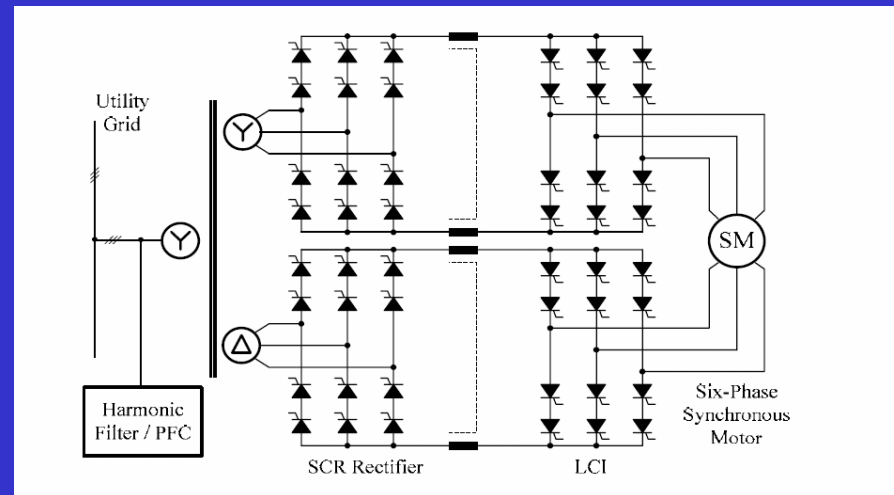
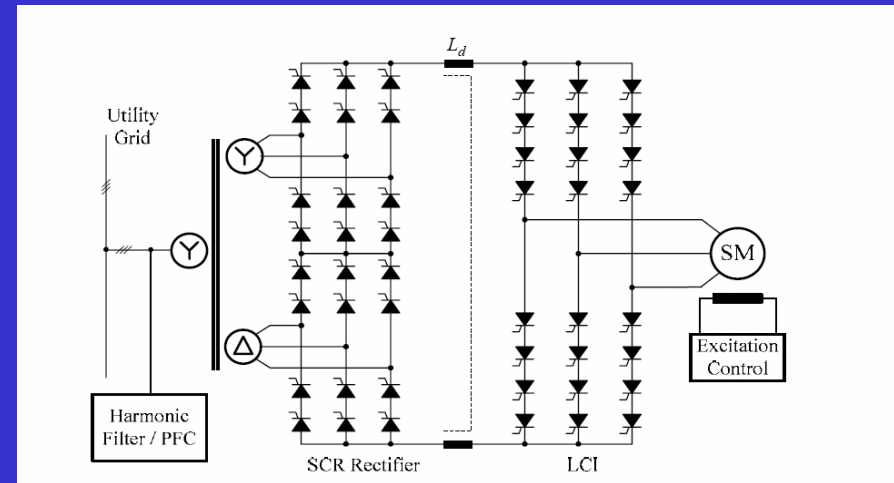


Topology Fundamentals – Current Source



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

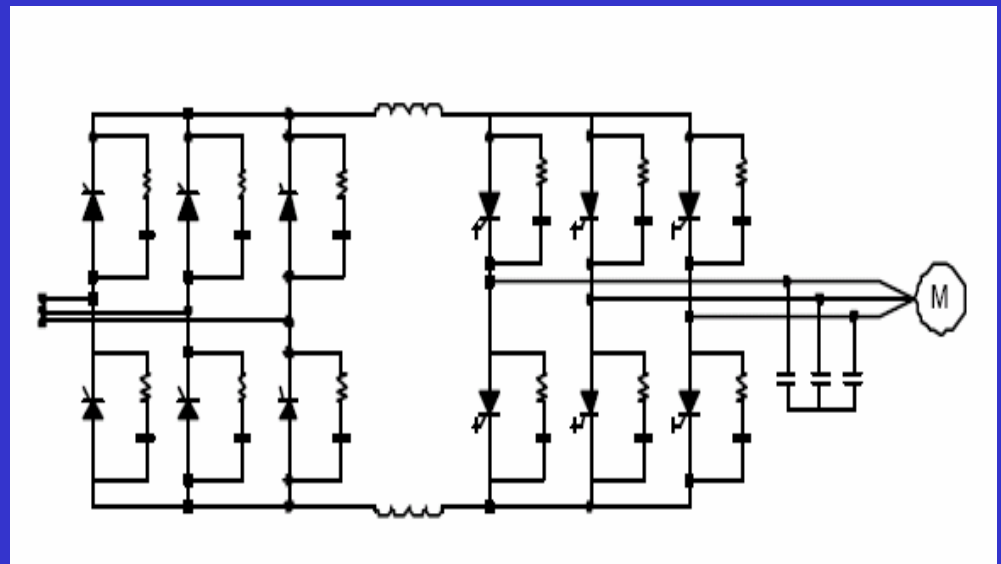
- Introduced in late 1980's
- SCR rectifier – active front end
- DC link inductor (1.0 pu)
- GTO inverter (PWM firing)
- Output capacitor (0.4 – 0.6 pu)
- Rectifier choices
 - 6 pulse
 - (line reactor or iso tfmr)
 - 12 pulse (iso tfmr)
 - 18 pulse (iso tfmr)

Inherently regenerative

Simple topology

Durable design – fault tolerant

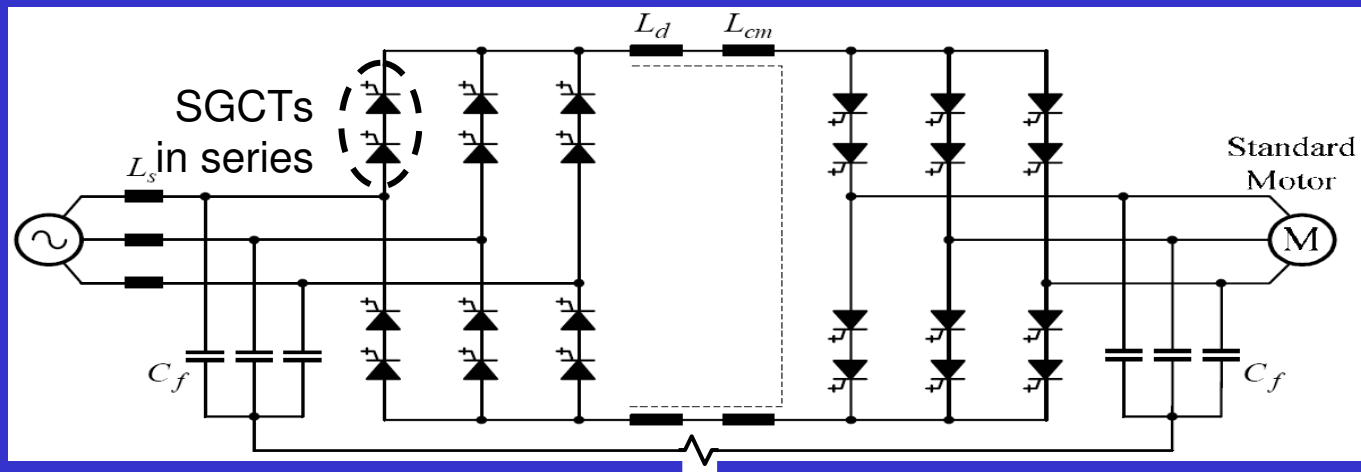
Line reactor version required motor insulation suitable to address CMV





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



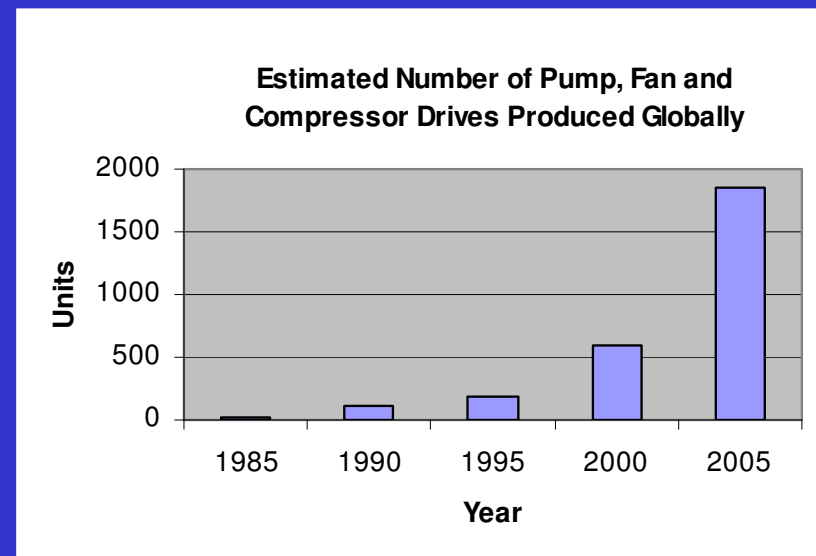
- ASDs have been used in process applications for some time – since 70's
 - Improved process control
 - Efficiency & energy savings
 - Allow starting on weak power systems within utility constraints
 - Eliminate mechanical components – valves, gearboxes, etc.
 - Reduce installation and maintenance costs
- 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 Southern Alberta Section PES/IAS Joint Chapter Technical Seminar



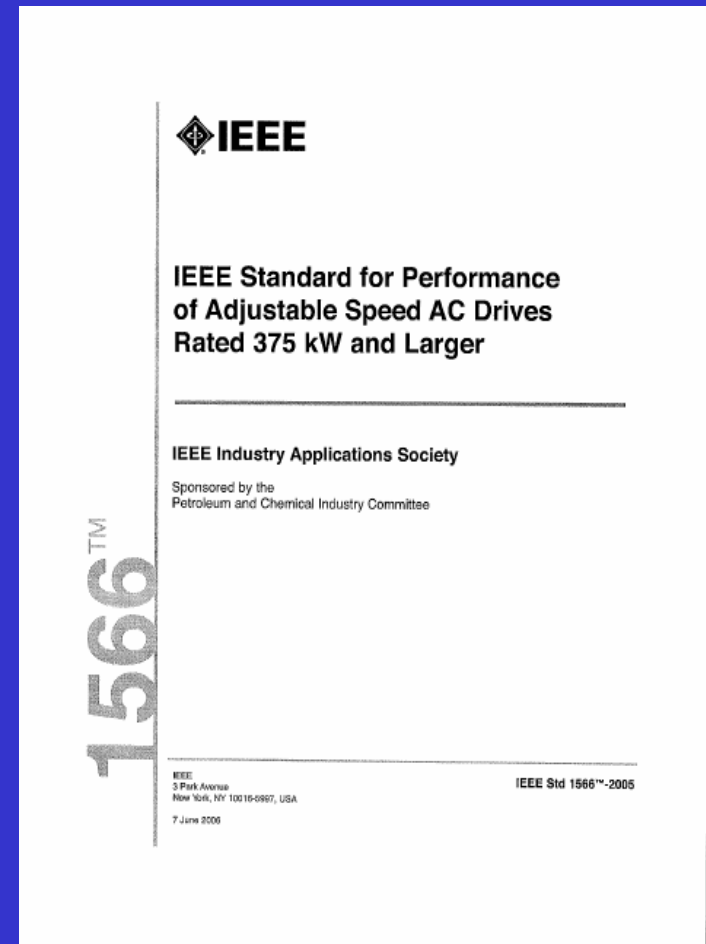
IEEE STD. 1566 STANDARD FOR PERFORMANCE OF ASD AC DRIVES RATED 375 KW AND LARGER



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 1566 Objectives



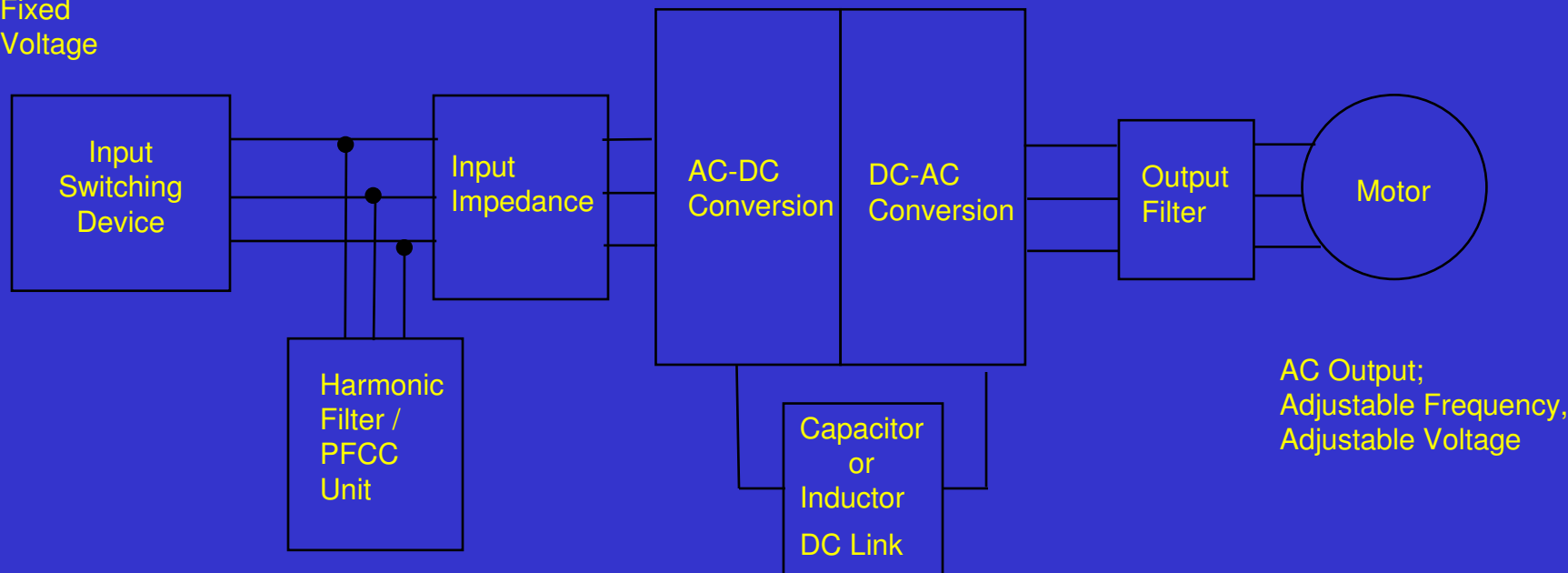
- Stand alone document
- Specify performance rather than design
- Provide the required data sheets
- Reduce confusion
- Reflect industry trends & needs
- Leverage on experience of numerous users
- Not all items which have been identified can be achieved immediately



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"

AC Input
Fixed
Frequency,
Fixed
Voltage



AC Output;
Adjustable Frequency,
Adjustable Voltage



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

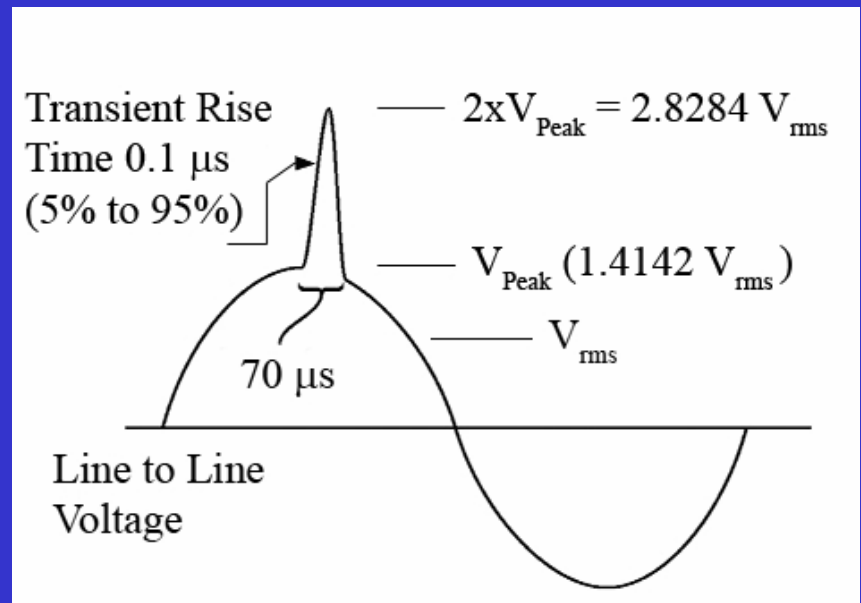
- Transient Voltages
 - Reliable operation with occasional input transients
- Flying Restart after 100% power loss of at least two seconds
- Voltage Sags



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 $0.1 \mu\text{s}$
- Base width of $70 \mu\text{s}$



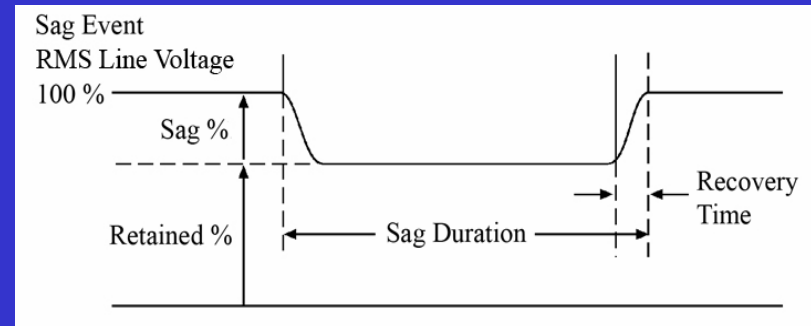


Voltage Sag



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





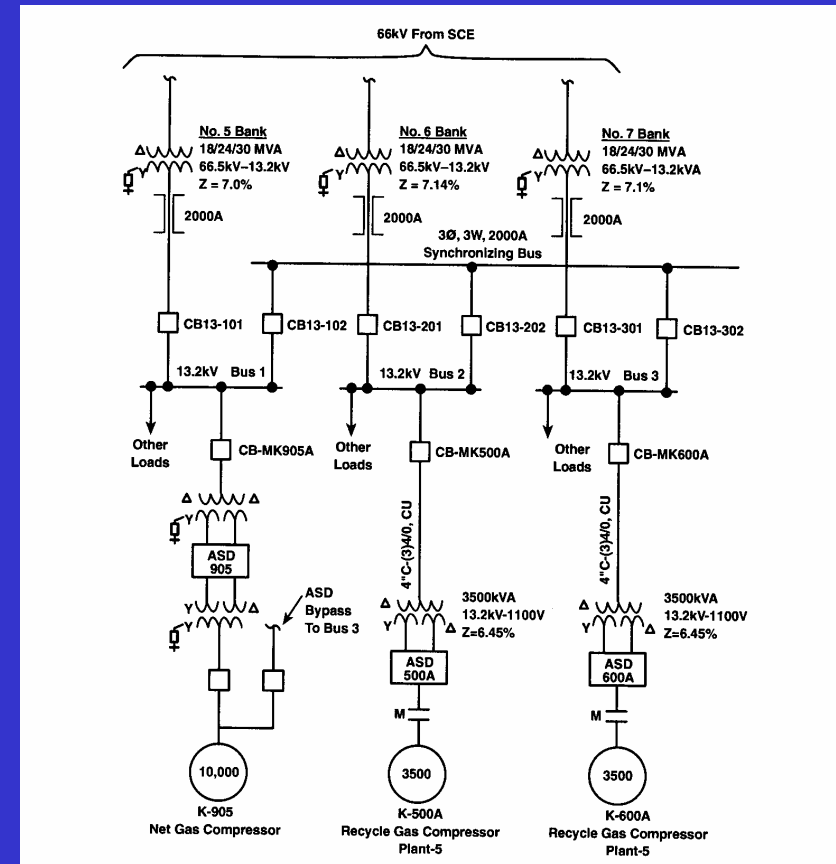
Harmonics and noise immunity

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

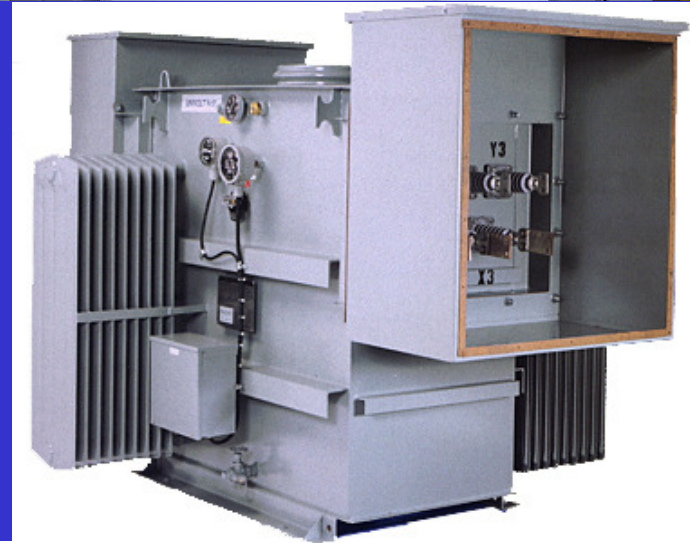
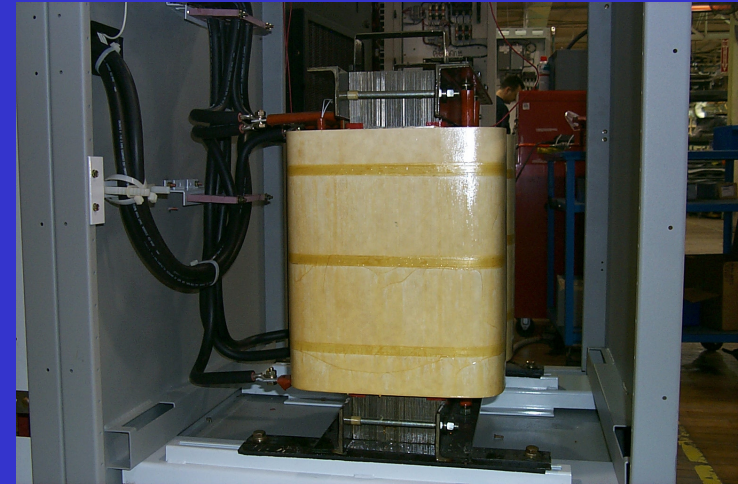


- Transfer motor between drive and utility, and back again
- Useful for starting duty (speed control not required) or approach to operational redundancy
- Must consider whether maintenance / repair can be performed on drive
- Multiple motors, one drive
- Various options available



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:
☐ 2400 V ☐ 3300 V ☐ 4160 V ☐ 6900 V ☐ 13800 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