



Specifying a Variable Frequency Drive's

Put on by Bruce Reeves and Jeremy
Gonzales

Dykman Electrical

Covering the Western US

For all of your VFD and Soft Start and
Motor Needs

How To Specify a Variable Frequency Drive

- **What is the application?**
- Is it a variable torque or Constant Torque?
- Is it heavy duty or light duty light

Variable Torque VS Constant Torque

- **First let's define these two terms above.**
- Variable torque applications: These AC motors have a speed torque characteristic that varies as the square of the speed. For example, a 1,800/900-rpm electrical motor that develops 10 hp at 1,800 rpm produces 2.5 hp at 900 rpm. Typical examples of some common variable torque applications are centrifugal pumps, fans, and blowers, (Positive displacement pumps not included.)

Variable Torque VS Constant Torque

- Constant Torque applications: These AC motors can develop the same torque at each speed, thus power output varies directly with speed. For example, an AC motor rated at 10 hp at 1,800 rpm produces 5 hp at 900 rpm. Typical examples of some common constant torque applications are mixers, conveyors, and compressors.

Variable Torque VS Constant Torque

- Light duty is typically reserved for variable torque applications and with some manufacturers the terms used are light or normal duty instead of variable torque. It is directly related to the overload capacity of the VFD, In Light or normal duty applications the overload is defined as being able to produce an overload of 120% for one minute.



Variable Torque VS Constant Torque


- Heavy duty is typically reserved for constant torque applications and with some manufacturers the term heavy duty is used instead of constant torque. Again it is directly related to the overload capacity of the VFD, In heavy duty applications the overload is defined as being able to produce an overload of 150% for one minute.

Variable Torque VS Constant Torque


- So these first two terms can and are used to describe the application and are critical in specifying a VFD

Motor Name Plate And What To Look For

MAX-PE™		PREMIUM EFFICIENCY INVERTER DUTY MOTOR		NEMA PREMIUM	
HP/kW	20/14.9	20/14.9	TYPE	AEHH8P	
Hz	60	50	CAT. NO.	NP0204	
VOLTS	230/460	190/380	FRAME	256T	
AMPS	46.0/23.0	56.6/28.3	ENCL.	TEFC	
R.P.M.	1760	1460	RATING	CONT.	
CODE	G	H	INS.	F	
S.F.	1.15	1.0	PHASE	3	
NOM. EFF.	93	91	AMB	40 °C	
MIN. EFF.	91.7	89.5	WEIGHT	311 Lb	
DESIGN	B	B	DE BRG	6309ZZ	
SER. NO.			ODE BRG	6307ZZ	
  Westinghouse <hr/> MOTOR COMPANY ROUND ROCK, TEXAS					





E89368



171832

CC002A





MADE IN TAIWAN
31045H420M3E9

Full Load Amps

- Full load amps should be used with HP in sizing a drive

Horsepower

- Even though Current is the big factor we still need to size the VFD for at minimum for the HP rating of the motor. We use the HP and current to properly size the VFD

RPM

- VFD's are typically built on the standards of a 4 pole 1800 RPM motor. The big key again is looking at HP and FLA to determine the proper size of the drive
- Lower RPM motors will typically have a higher FLA which should be reflected on the nameplate

Motor Cooling Method

- Important for setting the motor thermal overload protection. Is the motor a TEFC, Fan Cooled or other type of motor, these are settings we need to know in programming the drive
- Improper settings can cause alarms in the VFD

Generator Operation

- Be sure to properly size a generator to be sure the voltage and frequency considerations are properly met
- Marginal sized generators will cause problems with VFD operations
- Drives are typically rated for the below specs
 - +/- 10% voltage fluctuation Supply Voltage
 - +/- 3% frequency variation
 - Voltage sag ride-through for the following:
 - 0% voltage for 1 cycle
 - 60% voltage for 10 cycles
 - 87% voltage continuous

Single Phase input to a 3 Phase Motor

- VFD's can be used to supply a 3-phase drive with single-phase power, then the drive must be derated by 25% to 50% of its current-handling ability, which will require you to specify a larger-sized drive.
- Programming options might have to be disabled to allow this operation.

Enclosure Type

- NEMA 1: Open style drive only for mounting on a wall in or in an existing enclosure, If on a wall, end caps or gland plates might have to be ordered to accommodate conduit or connectors. This drive is open to the environment and unprotected from dust, water or other environmental hazards.

Enclosure Type

- NEMA 12: Dust tight and will be mounted in an enclosure with fans and filters
- NEMA 3R: Rain tight enclosure with fans and filters
- NEMA 4X: Wash down enclosure with heat exchanger or air conditioner instead of fans and filters Some drives can be purchased in a 4X configuration without an enclosure but typically have limited horse power ranges in this configuration

Control Methods for Variable Frequency Drives

- 2-wire control, only one switch is used to run the variable frequency drive. An open switch stops the drive, and a closed switch starts the drive. A second switch could reverse the motor with a run command.

Control Methods for Variable Frequency Drives

- With 3-wire control, two switches are used to run the drive. One switch is needed to stop, might be called drive enable and another to start the variable frequency drive. This allows an auxiliary contact from the start to "seal in" the RUN command, just like your more conventional motor starters. Along with this you would have another switch if you needed to reverse the direction.

Speed Reference Sources

- Digital Operator on the VFD, typically up and down arrow keys
- Speed Potentiometer. Allows the operator to set motor speed with pot.

Speed Reference Sources

- Analog Signal Follower. 4-20mA or 0-10VDC; must provide variable frequency drives with an isolated input; must use a twisted/shielded pair and keep wire away from 3-phase AC

Speed Reference Sources

- Selector switch speed selection. Allows operator to select from several preset speeds. Can also be used if the speed is being set via a PLC, and an analog output is not available.

Speed Reference Sources

- Communications. Allow variable frequency drives to communicate on a network, such as MODBUS, PROFIBUS, DEVICENET, or Ethernet/IP – AB Ethernet, enabling drive operation to be coordinated and monitored from a PC

Speed Reference Sources

- Switching the Digital Operator Panel to Local Control allows control of the VFD through the keypad for troubleshooting or operator preference

Now Sounds Confusing, why do you want to use a drive?

- Energy savings are usually the primary motivation for installing variable frequency drives for centrifugal applications, and variable torque drives offer the greatest energy savings.
- For example, a fan needs less torque when running at 50% speed than it does when running at full speed. Variable torque operation allows the motor to apply only the torque needed, which results in reduced energy consumption.

Now Sounds Confusing, why do you want to use a drive?

- Conveyors, positive displacement pumps, punch presses, extruders, and other similar type applications require constant level of torque at all speeds. In which case, constant torque variable frequency drives would be more appropriate for the job. Energy savings in these applications will not be the primary concern but there are other benefits to be gained

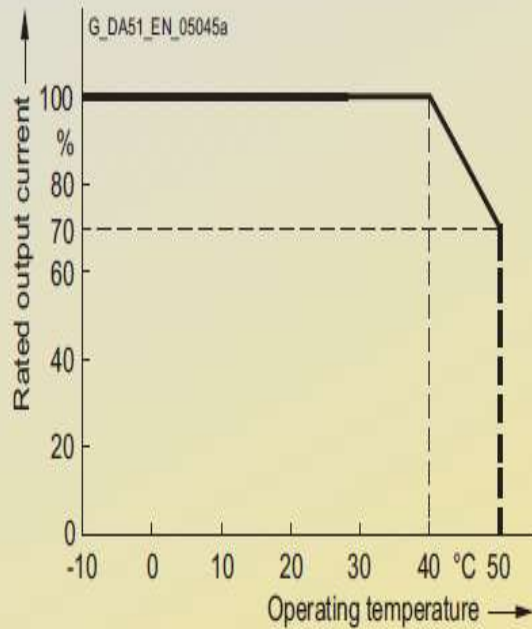
Just as important as energy savings is the control of the process

- Speed
- Flow
- Seasonal concerns
- Eliminating valves, dampers
- Added motor and other mechanical life by reducing inrush encountered in across the line starting

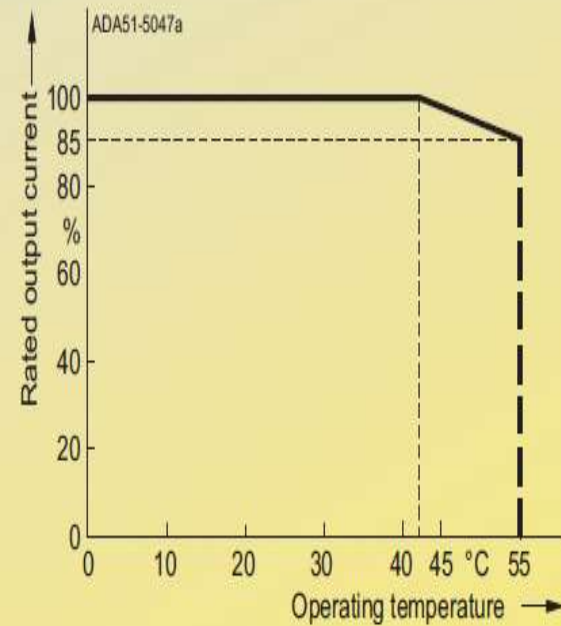
De-Rate for Temperature

Operating temperature

Inverter 7.5 kW to 90 kW



Inverter 110 kW to 250 kW



De-Rate for Carrier Frequency

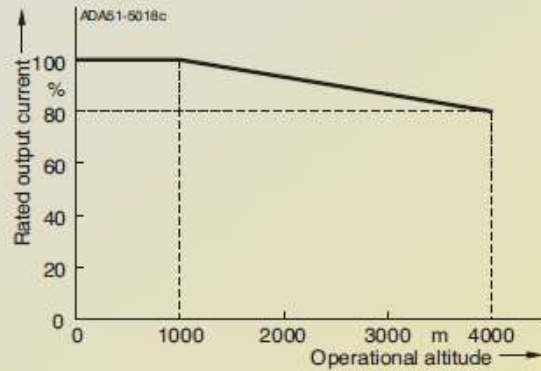
Pulse frequency

Output (for 3 AC 400 V) kW	Rated output current in A for a pulse frequency of							
	2 kHz	4 kHz	6 kHz	8 kHz	10 kHz	12 kHz	14 kHz	16 kHz
7.5	19.0	19.0	17.1	15.2	13.3	11.4	9.5	7.6
11.0	26.0	26.0	24.7	23.4	20.8	18.2	15.6	13.0
15.0	32.0	32.0	28.8	25.6	22.4	19.2	16.0	12.8
18.5	38.0	38.0	36.1	34.2	30.4	26.6	22.8	19.0
22	45.0	45.0	40.5	36.0	31.5	27.0	22.5	18.0
30	62.0	62.0	55.8	49.6	43.4	37.2	31.0	24.8
37	75.0	75.0	71.3	67.5	60.0	52.5	45.0	37.5
45	90.0	90.0	81.0	72.0	63.0	54.0	45.0	36.0
55	110.0	110.0	93.5	77.0	63.3	49.5	41.3	33.0
75	145.0	145.0	123.3	101.5	83.4	65.3	54.4	43.5
90	178.0	178.0	138.0	97.9	84.6	71.2	62.3	53.4
110	205.0	180.4	-	-	-	-	-	-
132	250.0	220.0	-	-	-	-	-	-
160	302.0	265.8	-	-	-	-	-	-
200	370.0	325.6	-	-	-	-	-	-
250	477.0	419.8	-	-	-	-	-	-

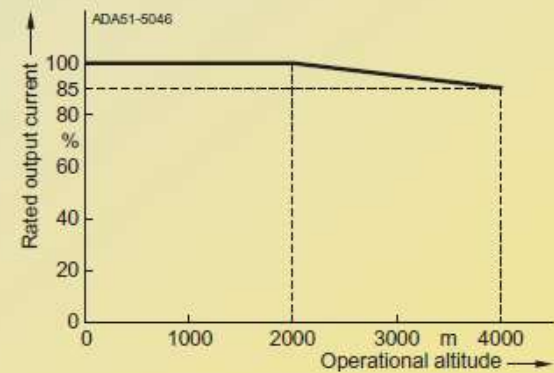
De-Rate for Elevation

Installation altitude above sea level

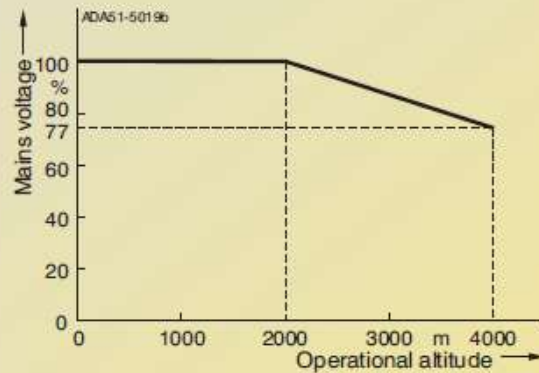
Permissible output current
in % of the rated output current
Inverter 7.5 kW to 90 kW



Inverter 110 kW to 250 kW



Permissible mains voltage
in % of the max. possible mains voltage
Inverter 7.5 kW to 90 kW



Inverter 110 kW to 250 kW

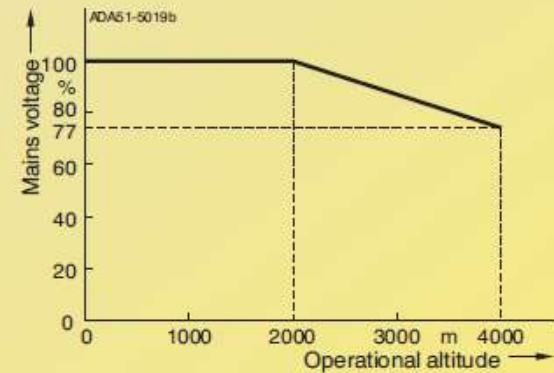


Table E.1 Recommended Fuse and Circuit Breaker Ratings per NEC (208-240Vac Input)

Model CIMR-P7U	Hp	Input Amps *1 (Continuous Rating)	Output Amps *1 (Continuous Rating)	Fuse Selection Criteria		Circuit Breaker Selection Criteria
				Maximum Time-Delay Fuse Rating (A)	Maximum Non-Time-Delay Fuse Rating (A)	Maximum CB Rating (A)
20P4	0.5/0.75	4.3	3.6	6	12	15
20P7	1	5.5	4.6	8	12	15
21P5	1.5/2	9.4	7.8	15	15	15
22P2	3	13	10.8	20	20	20
23P7	5	20	16.8	30	30	35
25P5	7.5	24	23	40	50	45
27P5	10	37	31	60	80	80
2011	15	53	46.2	80	80	100
2015	20	70	59.4	110	125	125
2018	25	89	74.8	125	150	150
2022	30	98	88	150	150	175
2030	40	120	115	200	200	225
2037	50	180	162	250	250	300
2045	60	212	192	300	300	350
2055	75	237	215	350	350	450
2075	75/100	350	312	450	450	600
2090	125	396	360	600	600	700
2110	150	457	415	700	700	900

*1 Input and Output Amps are based on the Normal Duty (ND) current rating. Consult the Specification section for details on the Heavy Duty (HD) and Normal Duty (ND) ratings.

Part Two: Addressing Potential Issues

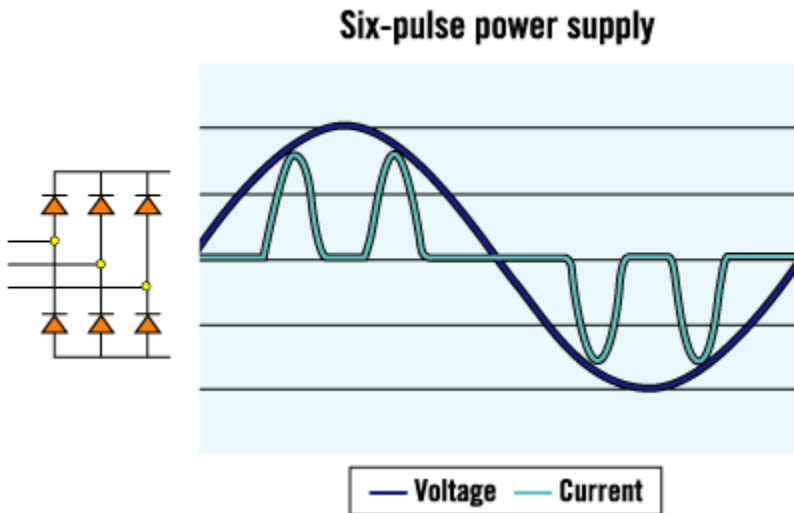
- **Harmonics – Meeting IEEE-519**
- **Common Mode Voltage (Bearing Fluting)**
- **Long Lead Lengths**

Harmonics

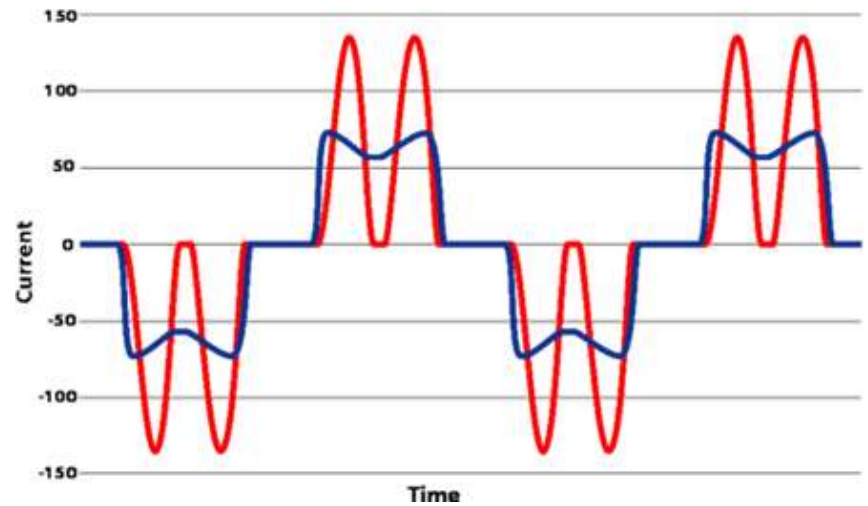
- Harmonics are caused by nonlinear loads.
- A nonlinear load is any electronic device using solid state power switching supplies to convert incoming AC to DC:
 - Personal Computers
 - Florescent Lighting
 - Uninterruptable Power Supplies (UPS)
 - Variable Frequency Drives

Harmonics

Current Distortion



Voltage and Current Distortion



Harmonics

- The distorted current reflected throughout the electrical system causes either a voltage drop or severe voltage distortion.

High Fault Current (Stiff System) – System Impedance is Low

Voltage distortion is low

Harmonic current draw is high

Low Fault Current (Soft System) – System Impedance is High

Harmonics

- High Fault Current (Stiff System) – System Impedance is Low
 - Voltage Distortion is Low
 - Harmonic Current Draw is High
- Low Fault Current (Soft System) – System Impedance is High
 - Voltage Distortion is High
 - Harmonic Current Draw is Low

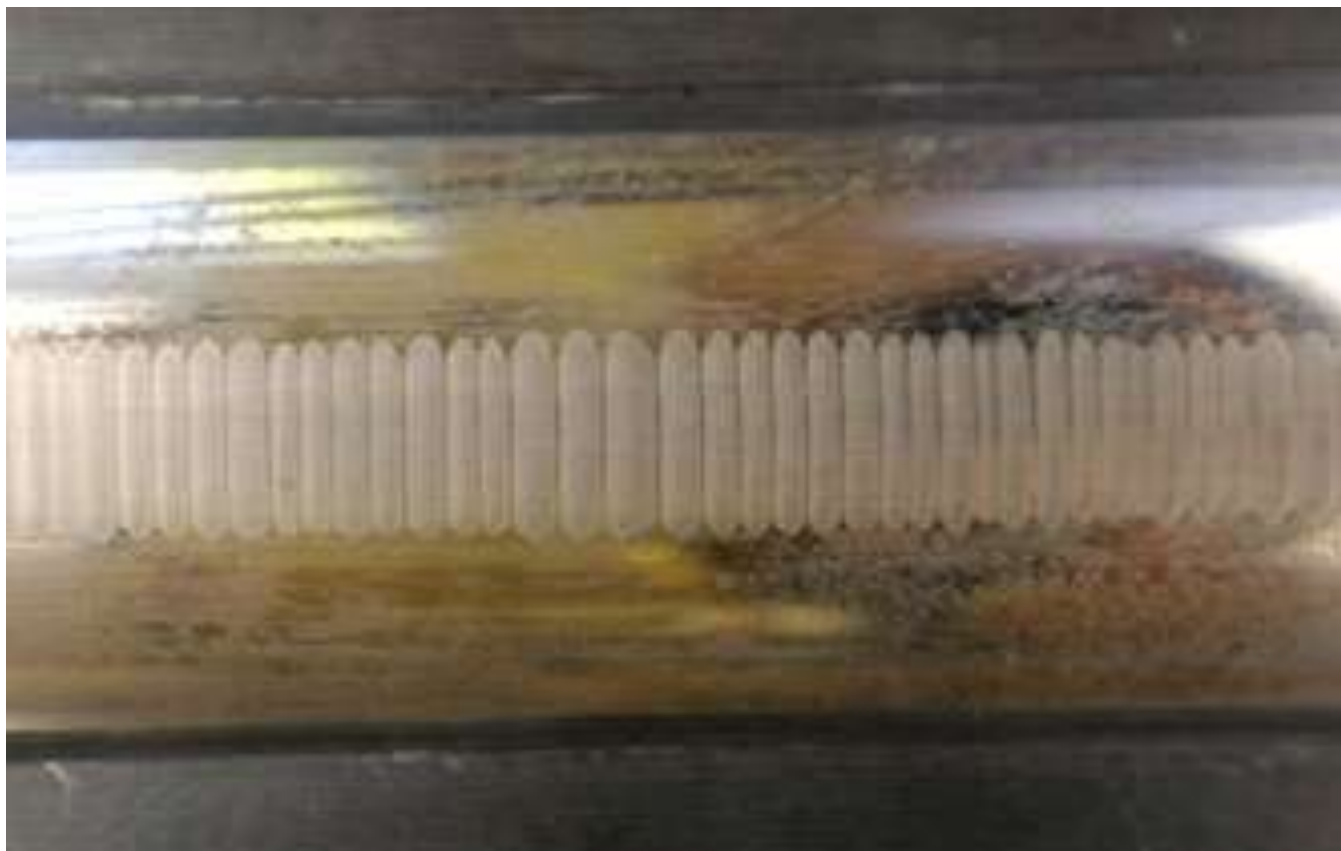
Harmonics

- Harmonics cause problems with the distribution system or equipment on the system.
 - Conductor Heating
 - Reduced Capacitor Life
 - False Trips or Failures of Breakers and Fuses
 - Transformer Overheating
 - Utility Meter can record measurements wrong
 - Affect the operation of other VFD's and Control Equipment

Harmonics

- There are several ways to reduce system harmonics:
 - **System Design** – Limit Non-Linear Load
 - **Multi-Pulse Front Ends** – Minimizes the order and magnitude by cancellation
 - **Isolation Transformers** – Provides a neutral ground reference to reduce nuisance ground faults
 - **Line Reactors** – Adds system Impedance to reduce harmonics
 - **Harmonic Filters** – Either tuned or passive; to eliminate harmonics (5th, 7th, 11th...etc.)
 - **Active Front End** – Uses IGBT's on front end of VFD; uses a higher switching frequency than the system to reduce harmonics

Bearing Fluting

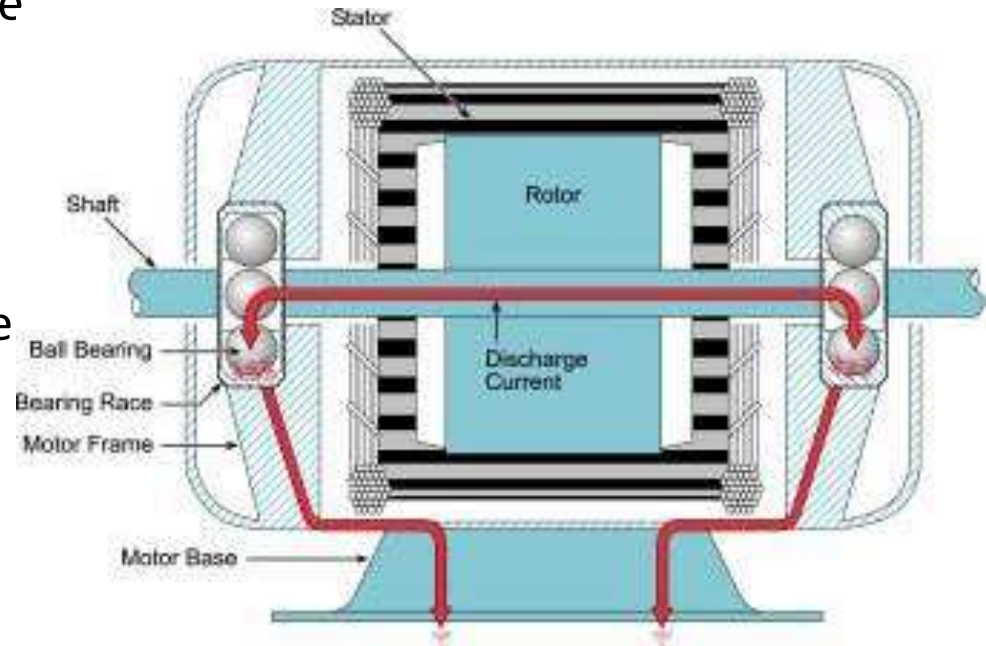


Bearing Fluting

- Electrical fluting occurs when a current is passed through the motor bearing instead of a grounded source
- PWM (Pulse Width Modulated) drive switching frequencies result in undesirable motor shaft currents

Bearing Fluting

- When the motor shaft is turning, the bearing grease insulates the bearing balls and the bearing race. The motor bearings and the race act as two capacitors. The stator and the rotor generate charge accumulation through capacitive coupling that is electrostatically induced in to the motor shaft. This current then passes through the motor shaft to the bearings and discharges from the balls with enough energy to pit the bearing race



Bearing Fluting

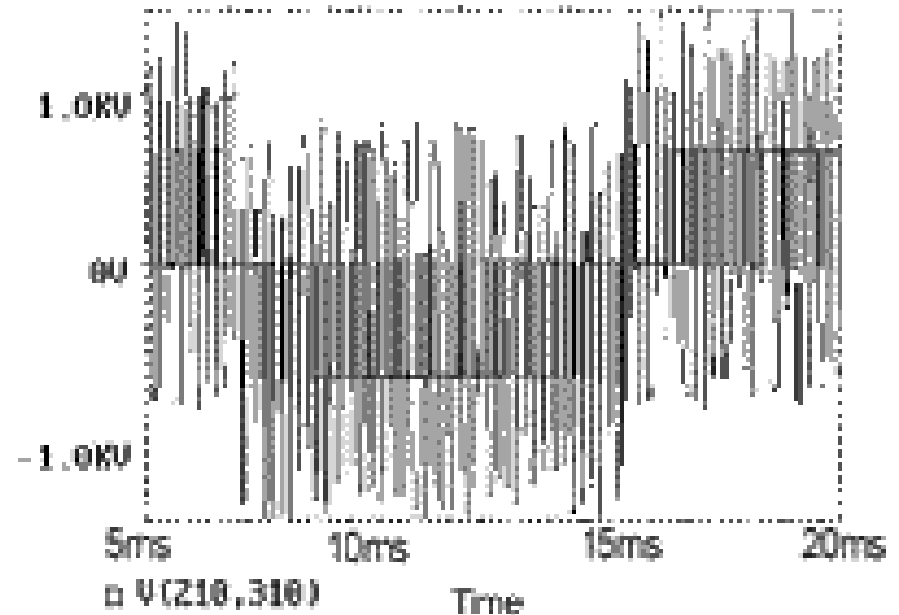
- There are several solutions to mitigating bearing fluting issues
 - **Shaft Grounding Brush** – Diverts shaft currents from bearings directly to ground
 - **Insulated Bearings** – Bearing ball, roller or race is insulated with a non conducting material
 - **Faraday Shield** – Conductive strips of foil placed across the stator slot that is grounded to the frame
 - **Filtering** – dV/dT filters will mitigate Common mode voltage but not eliminate them

Long Lead Lengths

- Some motors used with VFD's fail unexpectedly
- Common failure is a phase to phase or a phase to stator short in the first turn of the windings
- The cause of this failure is voltage overshoot

Long Lead Lengths

- The overshoot is caused by the inherent rise time of IGBT's plus the capacitance of the motor cable and motor windings
- Voltage Spike can reach upwards of 2000V
- Motor insulation – is generally rated between 1200 ~ 1600V



PWM Voltage, at motor terminals, without KLC

Long Lead Lengths

- Base line VFD – less than 150 feet
- Inverter Duty Motor – Dependant on manufacturer
- Reactor at VFD Output – Up to 300 feet
- Reactor at Motor Input – Up to 650 feet
- Output dV/dt Filter – Up to 2000 feet
- Sine Wave Filter – infinite lead length possible
- Multistep Output - Infinite lead lengths possible

Questions

