VFD Training

Training Agenda

1. Why use a VFD / Proper control of systems for efficiency
2. Using all VFD efficiency features
3. VFD theory of operation
4. Basic power structure
5. Installation requirements
6. Motor compatibility
7. VFD options
8. Enclosure types
9. BAS interface
10. Spare VFD’s?

Energy Savings

Centrifugal Fan & Pump **Affinity Laws**

CFM $\propto$ Speed	**(1)**
Static Pressure $\propto$ Speed^2	**(2)**
Torque $\propto$ Speed^2	**(3)**
Horsepower $\propto$ Speed ^{3}	**(4)**

Energy Requirements of Centrifugal Loads

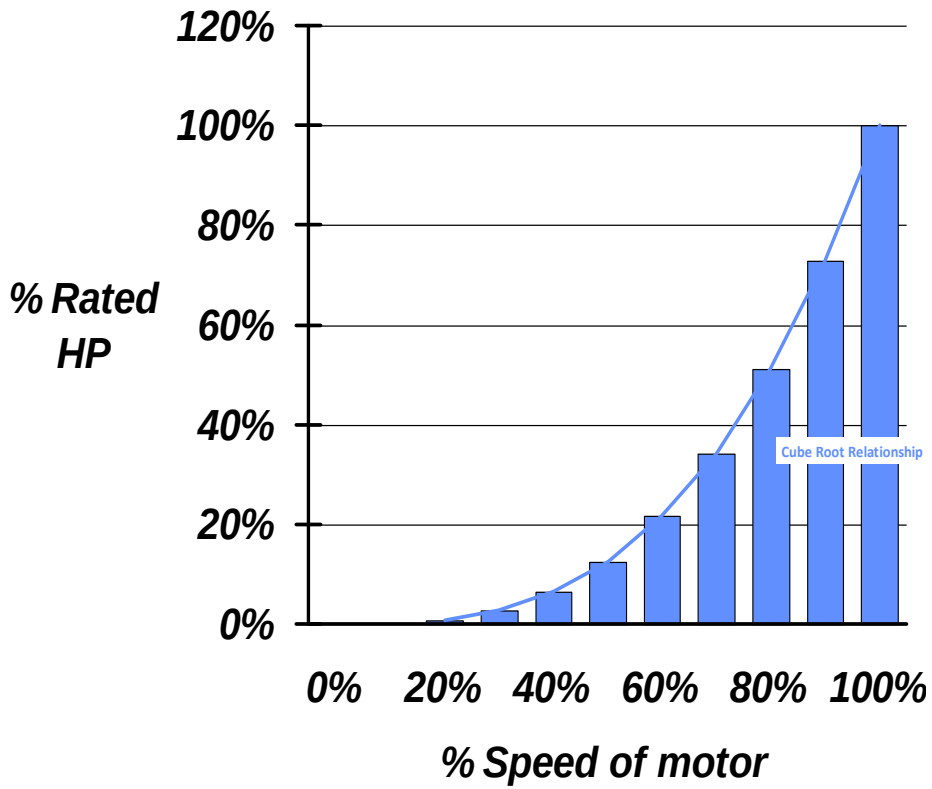


ABB Drives

Fan Power Consumption

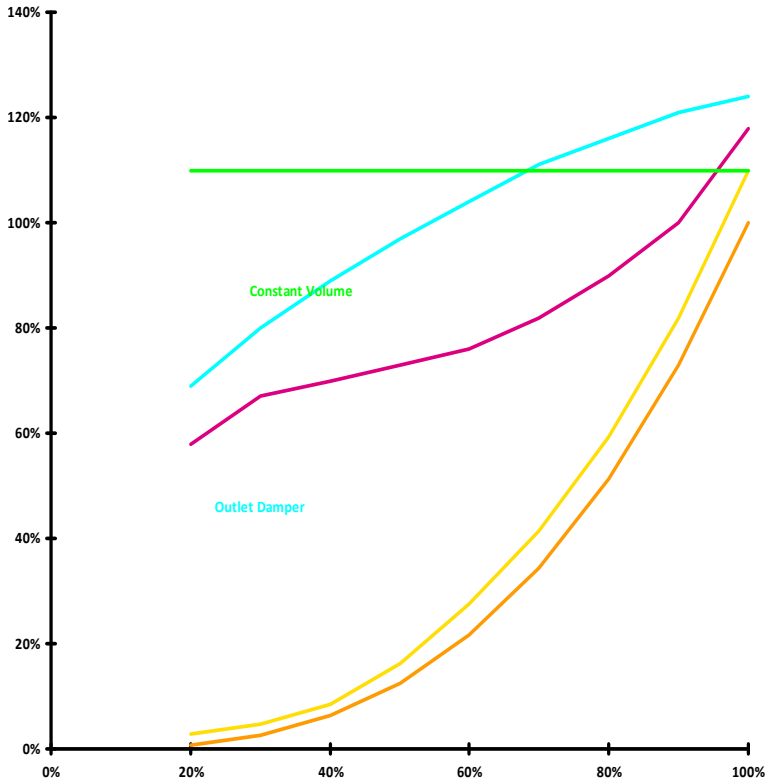


ABB Drives

Example assumptions:

It is assumed that the drive is to operate 24 hours / day, 7 days / week and 52 weeks / year.

It will be assumed that the system requires a 100 Hp prime mover.

Energy Analysis

Efficiency = power out / power in

% Speed	% Efficiency
100	93
90	92
80	89
70	87
60	81
50	70
40	50
30	32

The following duty cycle will be assumed:

% Speed	% Time
100	2.5
90	7.5
80	10
70	15
60	22
50	22
40	21

Typical VAV System Duty Cycle

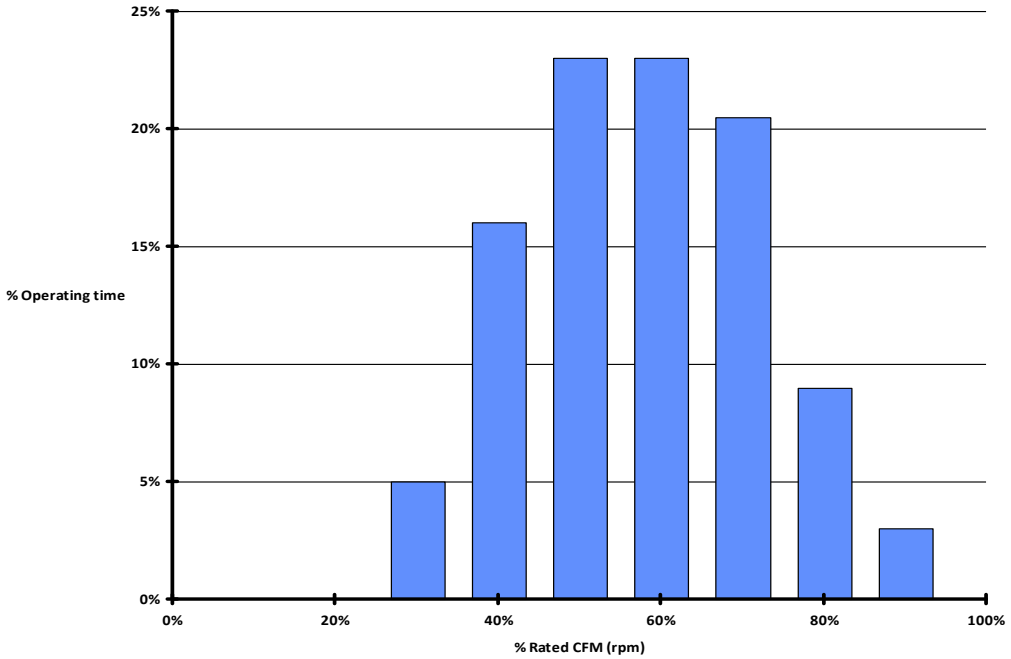


ABB Drives

Required Output - KW

% Speed	% Flow	% HP	Required Output (KW)
100	100	100	74.6
90	90	72.9	54.4
80	80	51.2	38.2
70	70	34.3	25.6
60	60	21.6	16.1
50	50	12.5	9.3
40	40	6.4	4.8

Required Input – KW & Duty Cycle

74.6 / .93 = 80.2

54.4 / .92 = 59.1

38.2 / .89 = 42.9

25.2 / .87 = 29.0

16.1 / .81 = 19.9

9.3 / .70 = 13.3

4.8 / .50 = 9.6

Hours / Year at Various Flows:

% Speed	% Time	Total Hrs/Yr	Hrs/Yr/speed
100	2.5	8760	219
90	7.5	8760	657
80	10	8760	876
70	15	8760	1314
60	22	8760	1927
50	22	8760	1927
40	21	8760	1840

Total KWH / Year

80.2 X 219 = 17,564

59.1 X 657 = 38,829

42.9 X 876 = 37,580

29.0 X 1314 = 38,106

19.9 X 1927 = 38,347

13.3 X 1927 = 25,629

9.6 X 1840 = 17,664

213,719

Energy Savings

Constant Speed System

687,900 KWH/YR X $.10/KWH = $68,790 / YR

VFD System

213,719 KWH/YR X $.10/KWH = $21,372 / YR

Constant Speed Vs AF System

$68,790 - $21,372 = $47,418 in savings per year

Golden Nuggets for a successful installation

- **Large amount of operating hours**
- **Large amount of <u>partially loaded</u> operating hours**
- **A variable volume system or retrofit to VAV plans***
- **Verify motor full load amp draw, not just listed HP**
- **Ensure controls in place for maximum savings but ensures comfort (very important)**
  - For parallel motor applications run both motors at half speed, not only one motor at full speed
- **Install VFD per manufactures guidelines!**

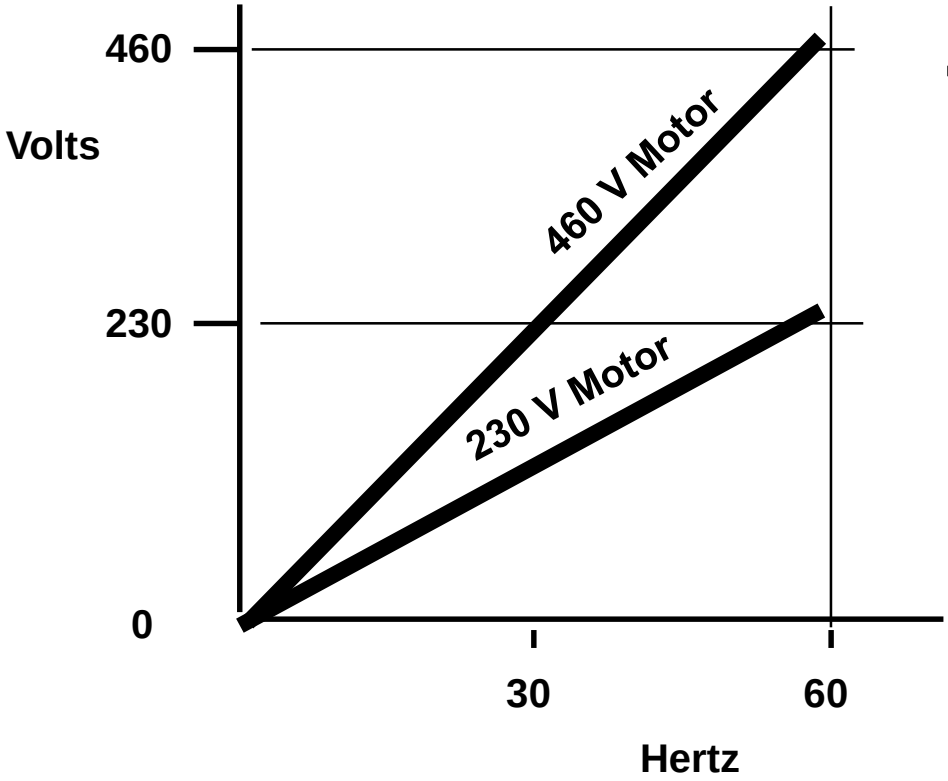
Other reasons to use a VFD?

- More energy savings
  - Running a centrifugal load at 50% speed on a **100HP** motor only uses 15HP but delivers 50% flow!
  - Improves power factor to .98
- Soft start feature increases lifespan of mechanical loads and helps reduce demand charges, and water hammer, etc
  - Much better than reduced voltage start
- Inherent protection for single phase, overload, short circuit and ground fault

Using the VFD energy saving features

- https://www.youtube.com/watch?v=lEX_EO2vsB8

What is a Drive / VFD/ AFD/ASD?

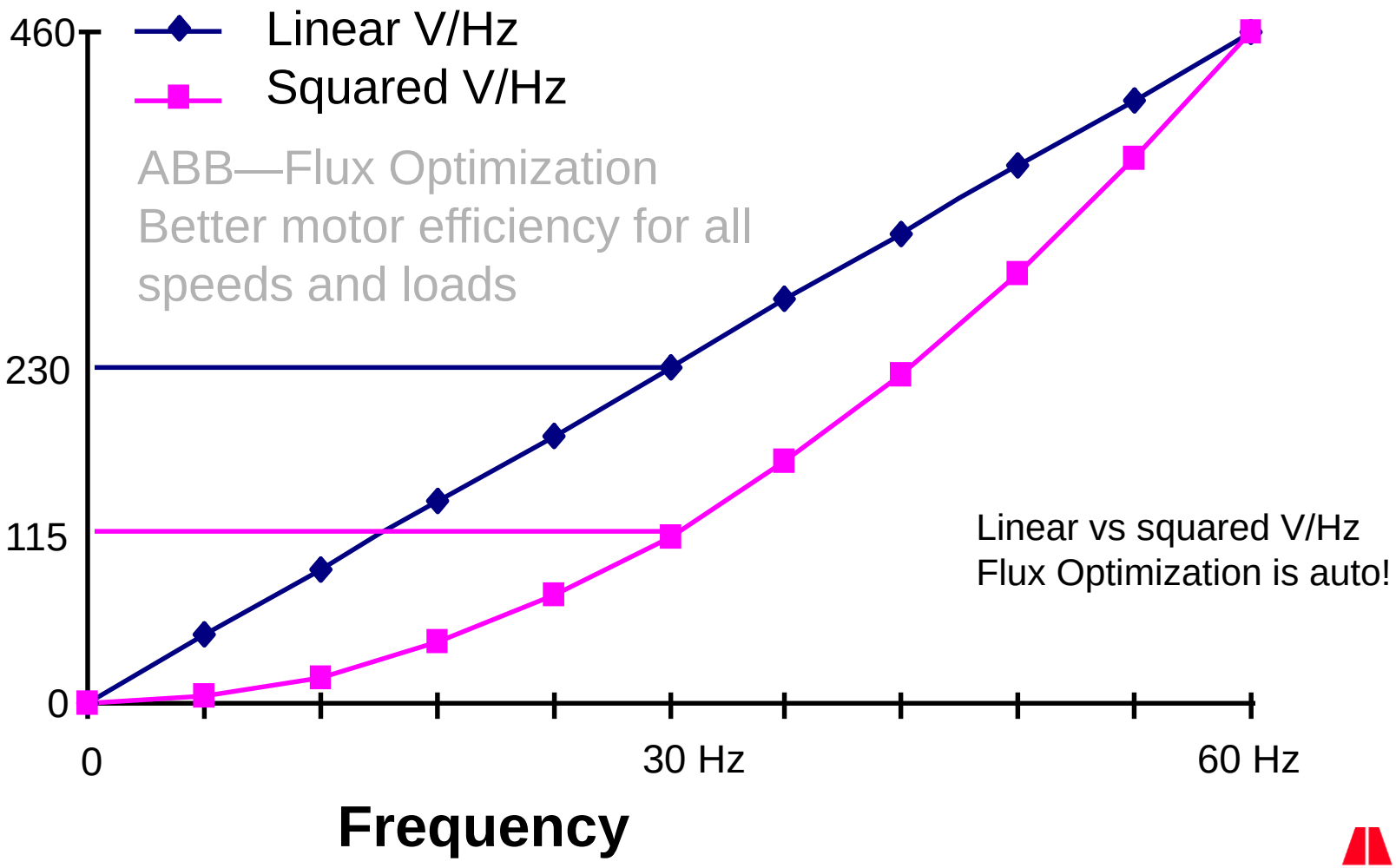


$$\frac{460\ \text{V}}{60\ \text{Hz}} = 7.67\ \frac{\text{V}}{\text{Hz}}$$

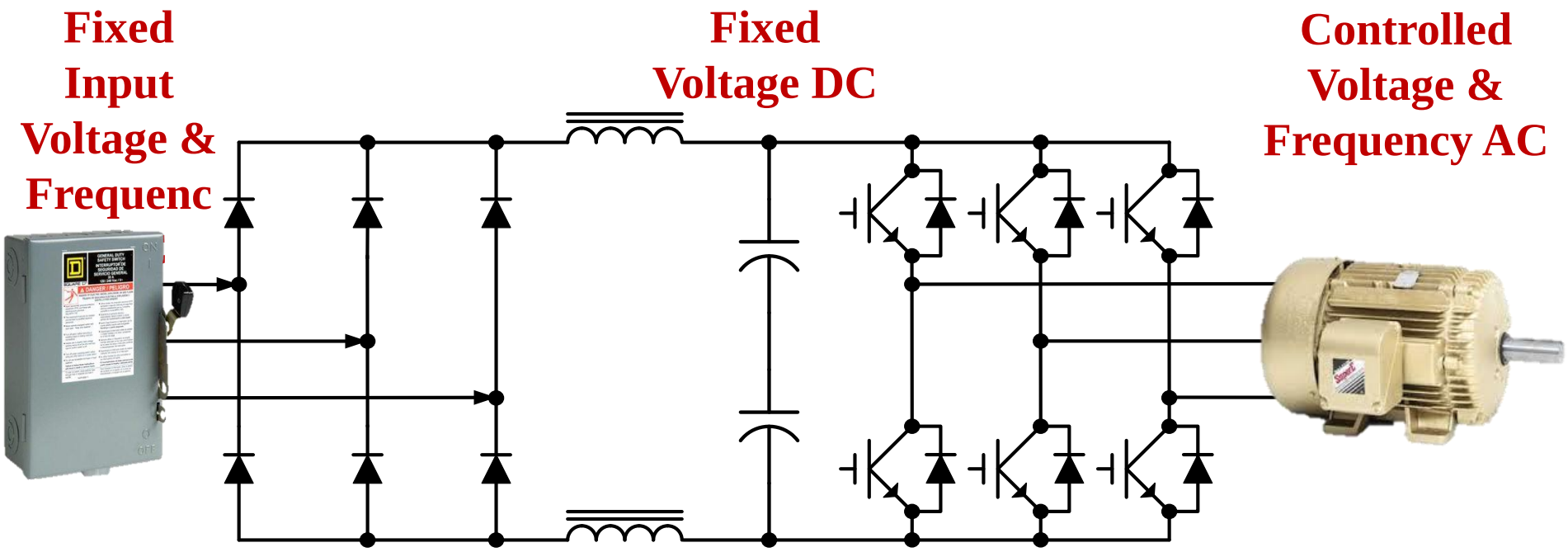
If 230 VAC Power Line:

$$\frac{230\ \text{V}}{60\ \text{Hz}} = 3.83\ \frac{\text{V}}{\text{Hz}}$$

VFDs Control Frequency and Voltage



VFD Basics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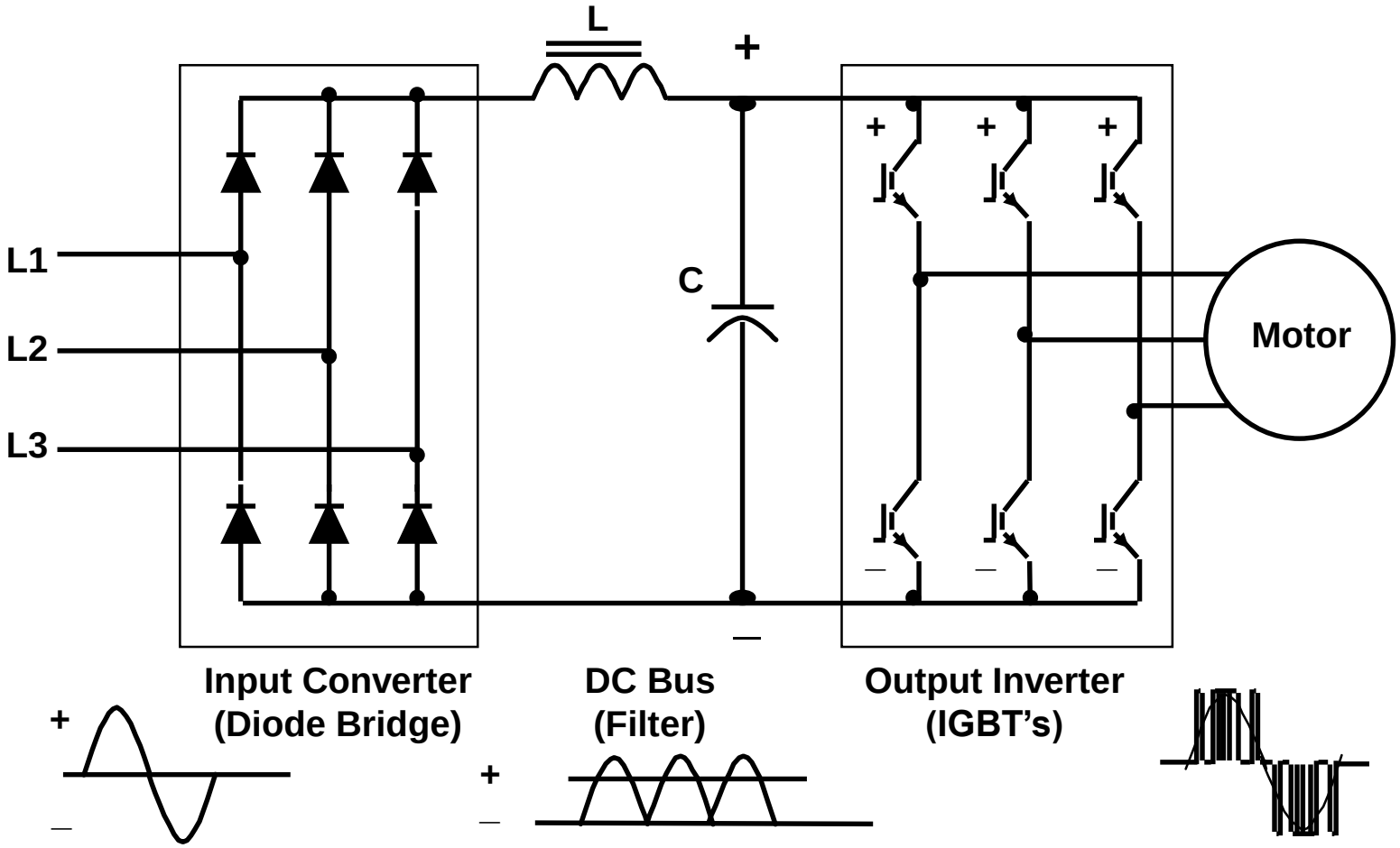
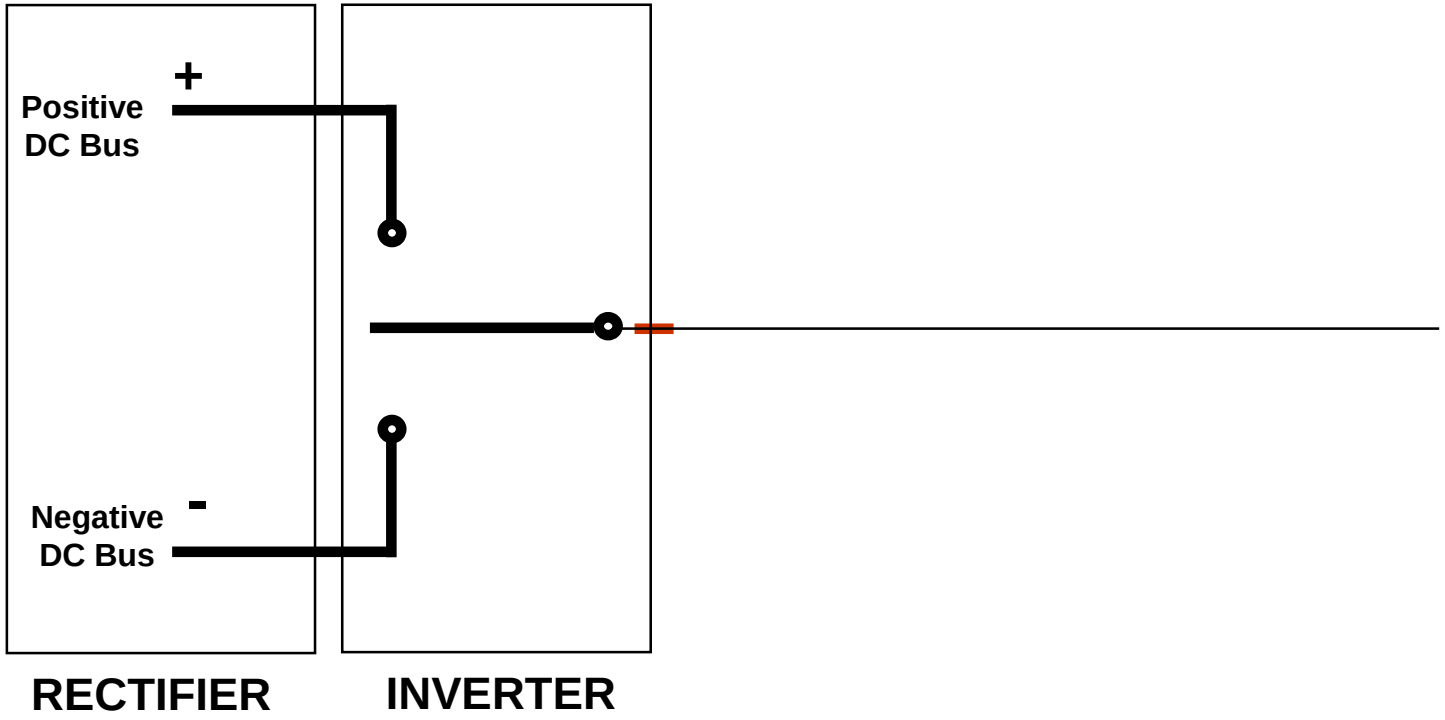
How VFD's Operate

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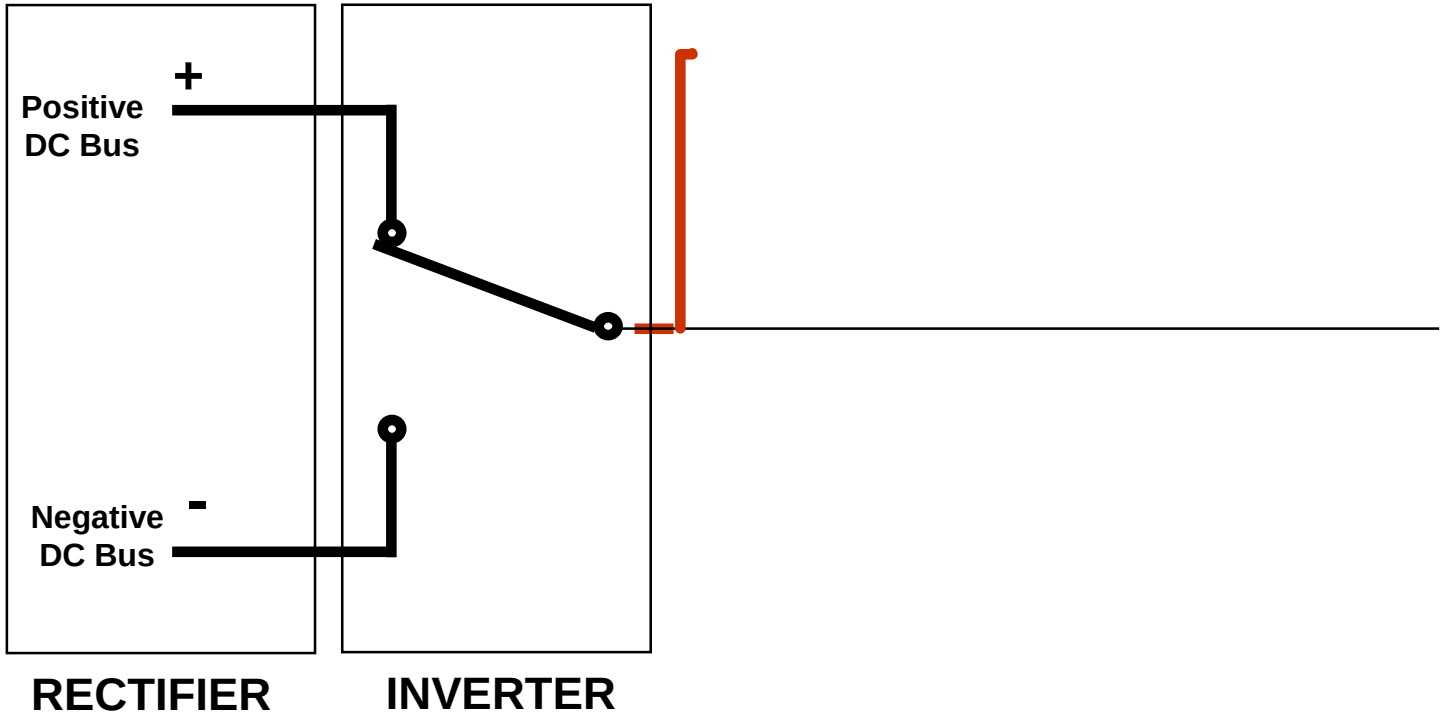
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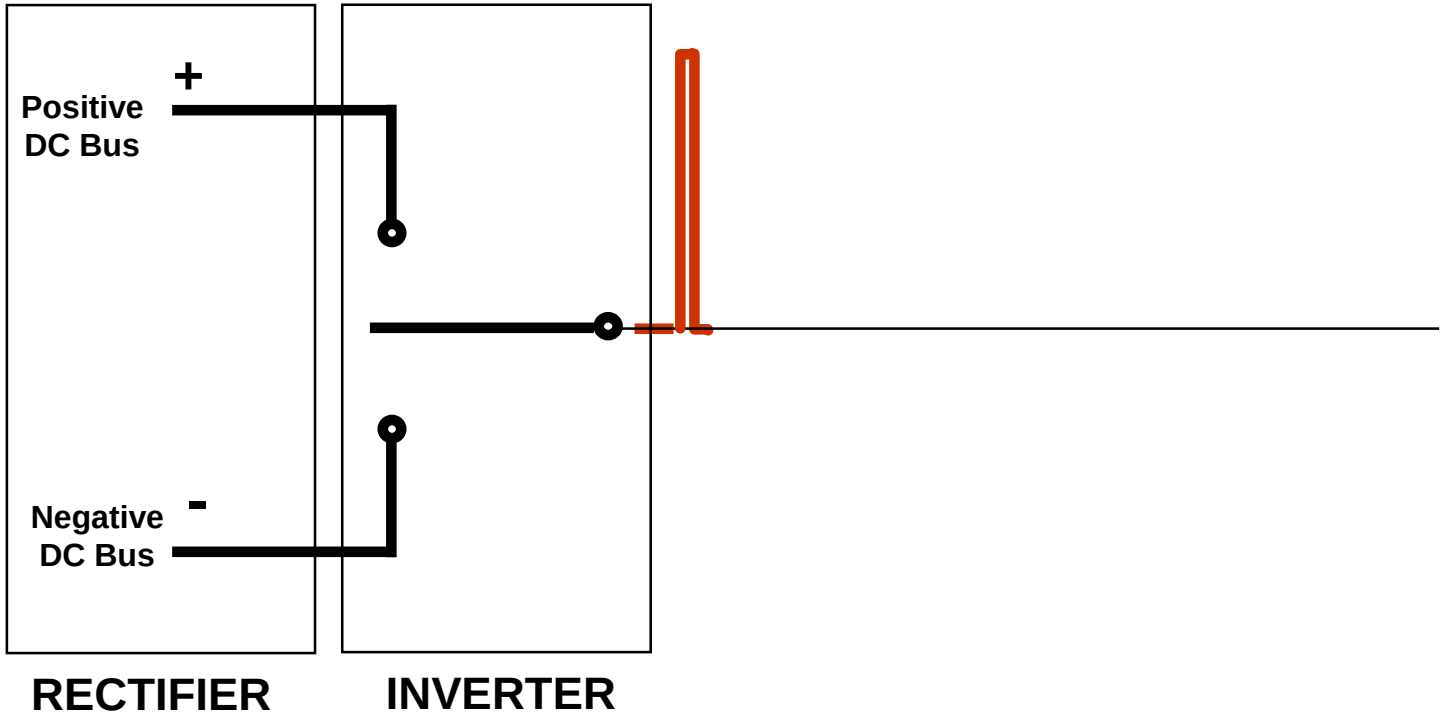
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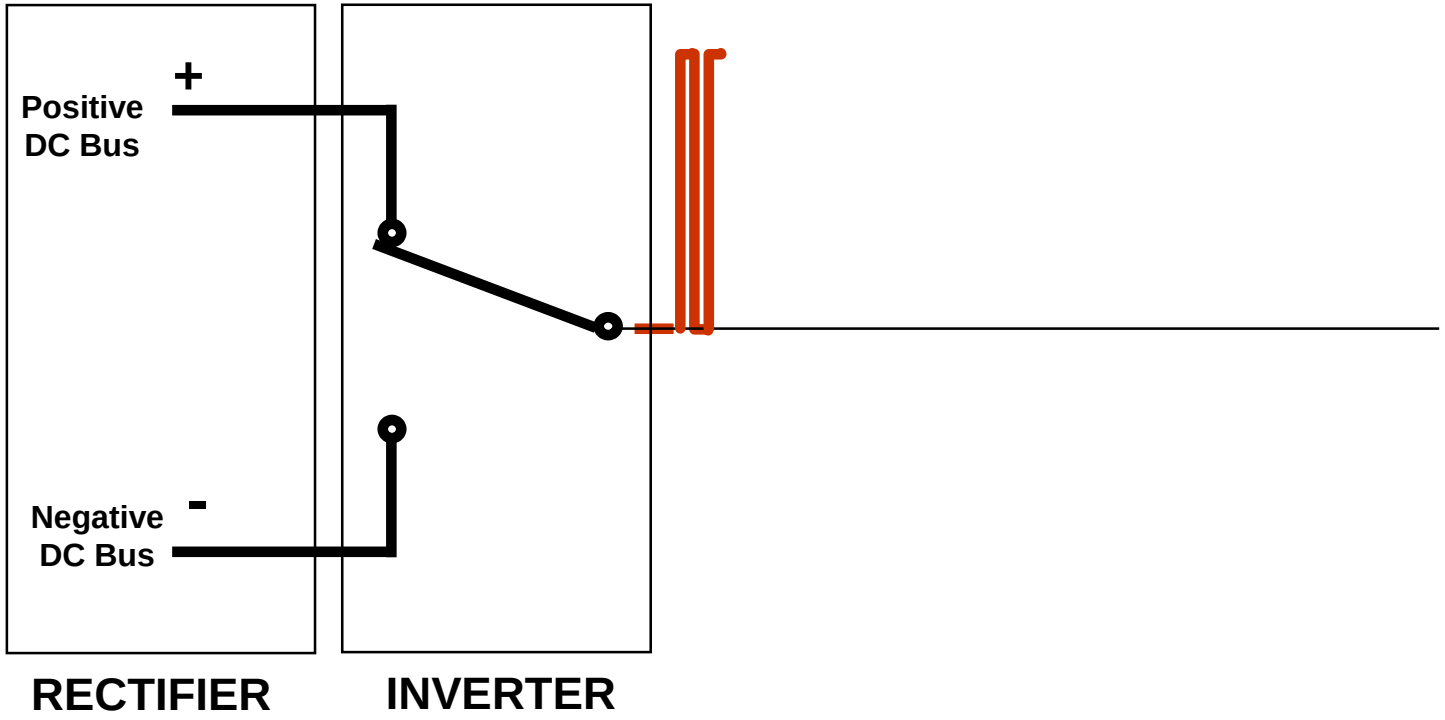
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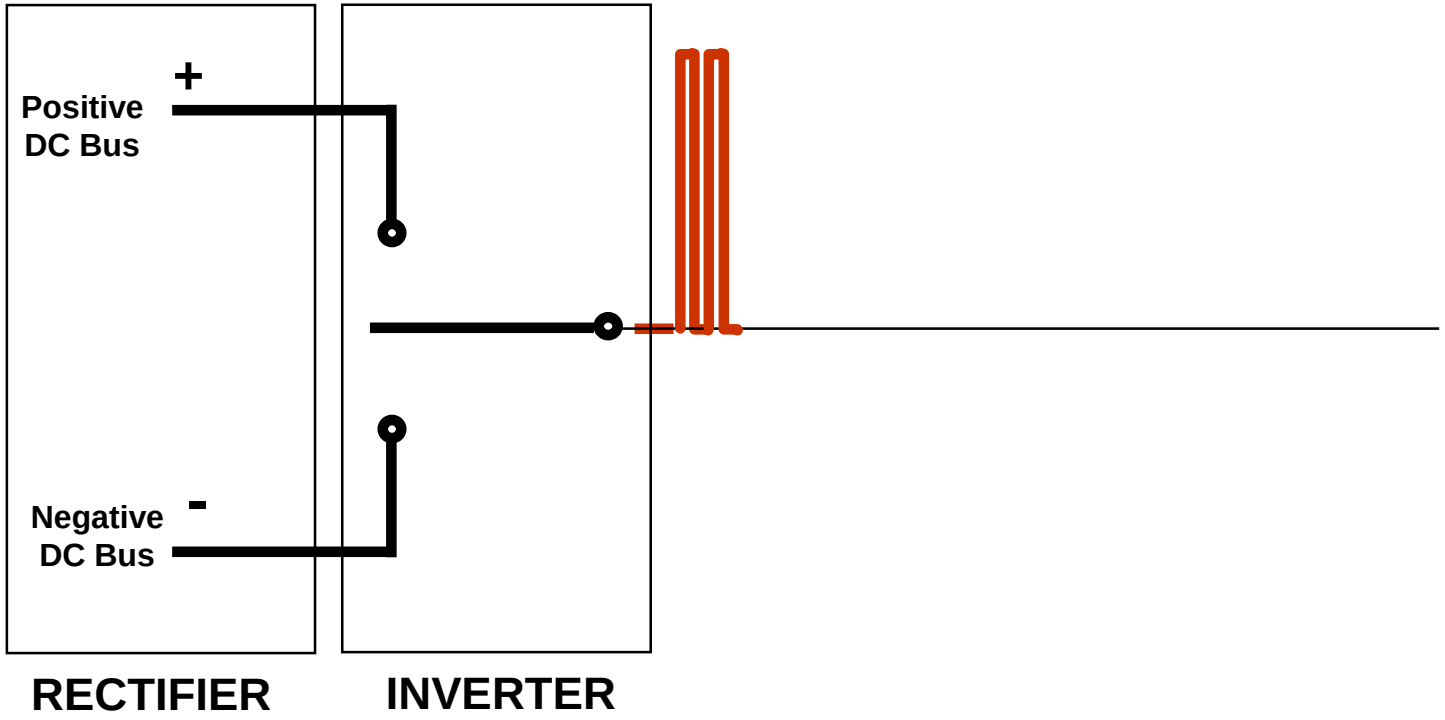
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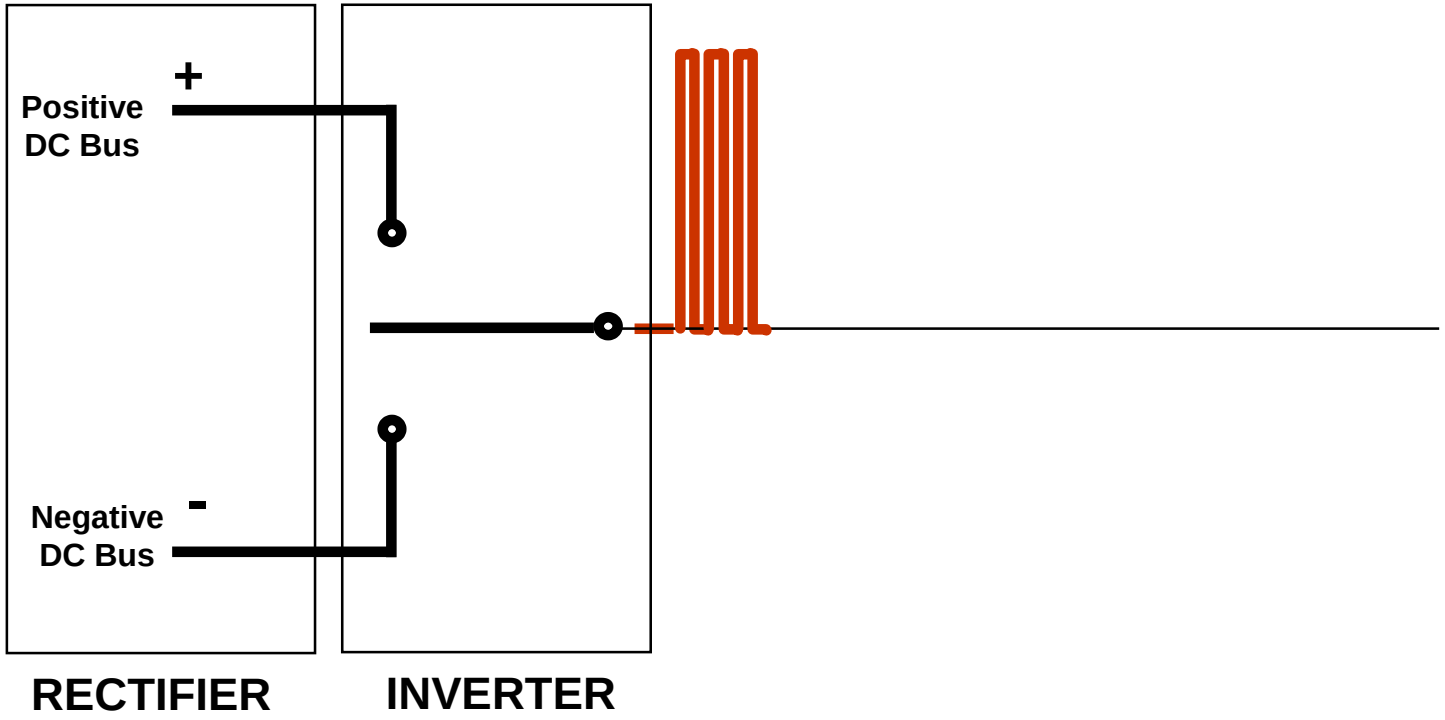
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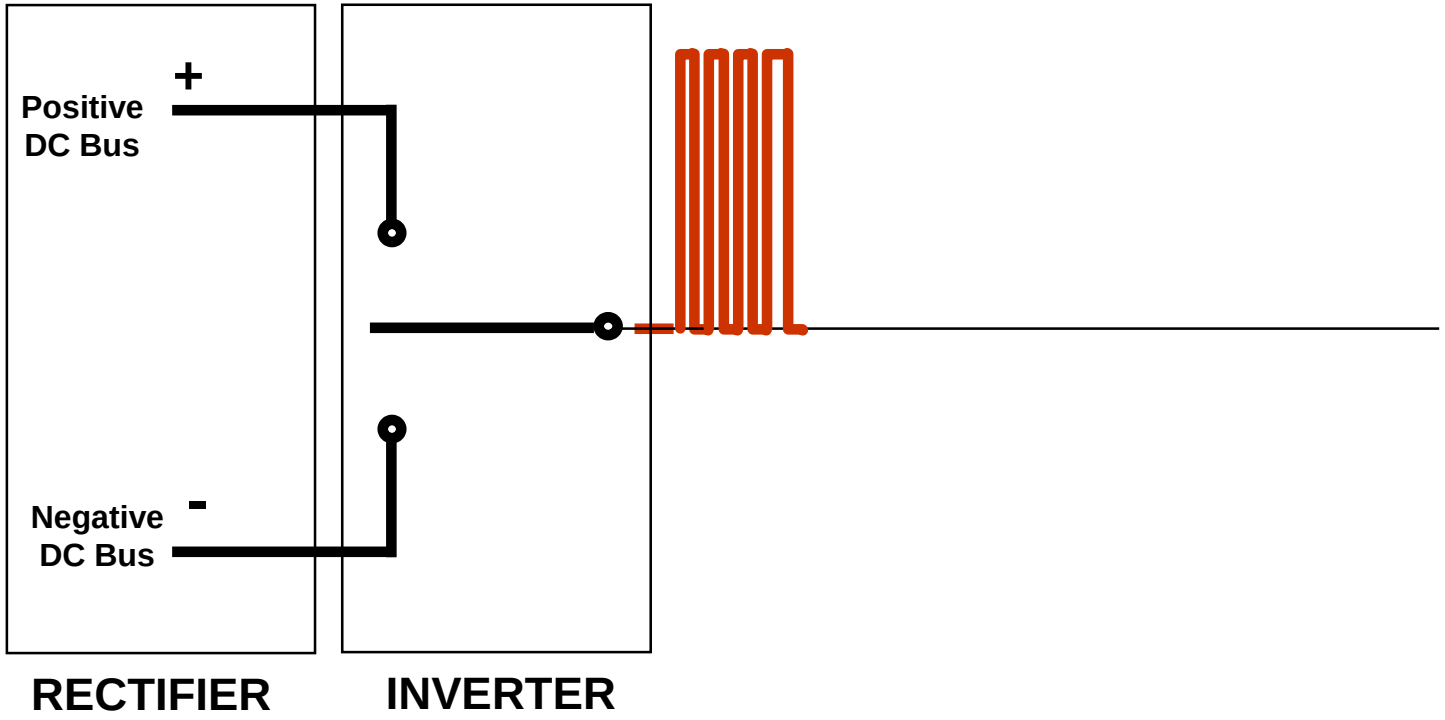
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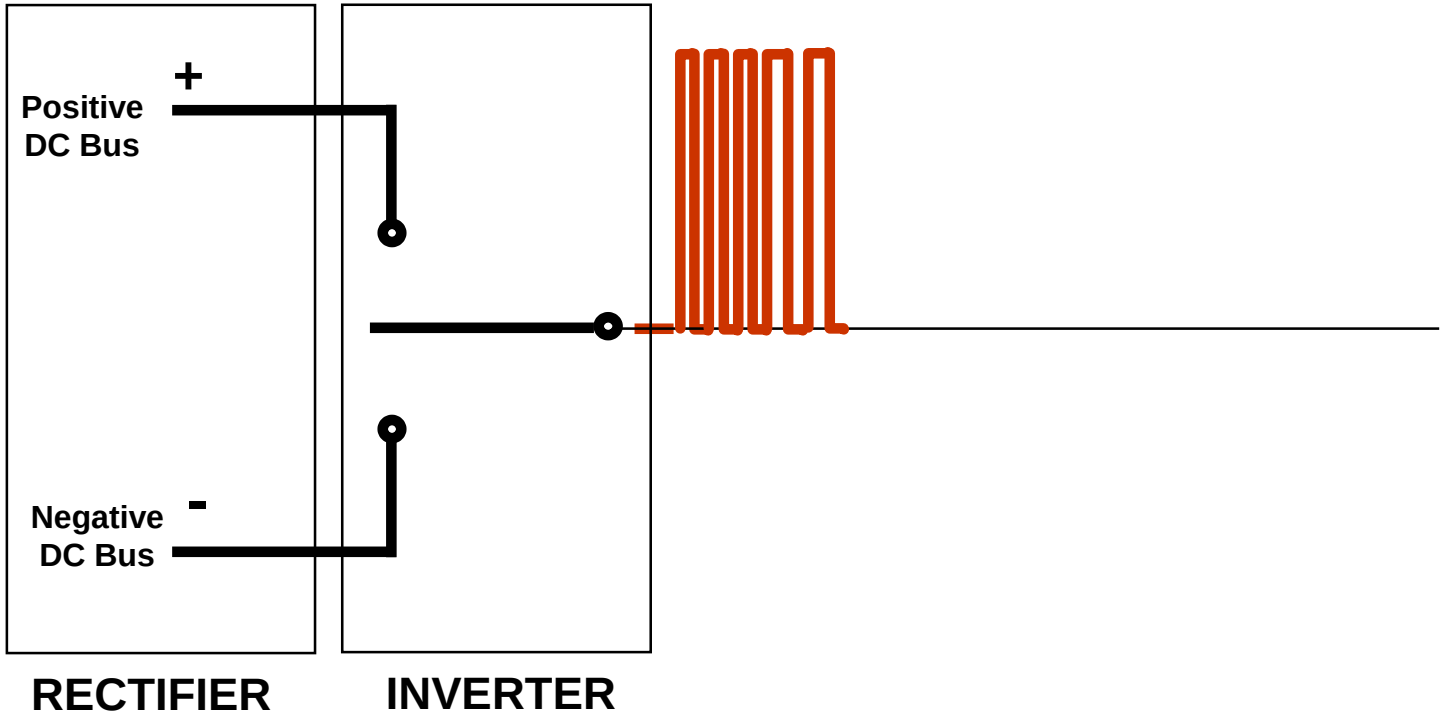
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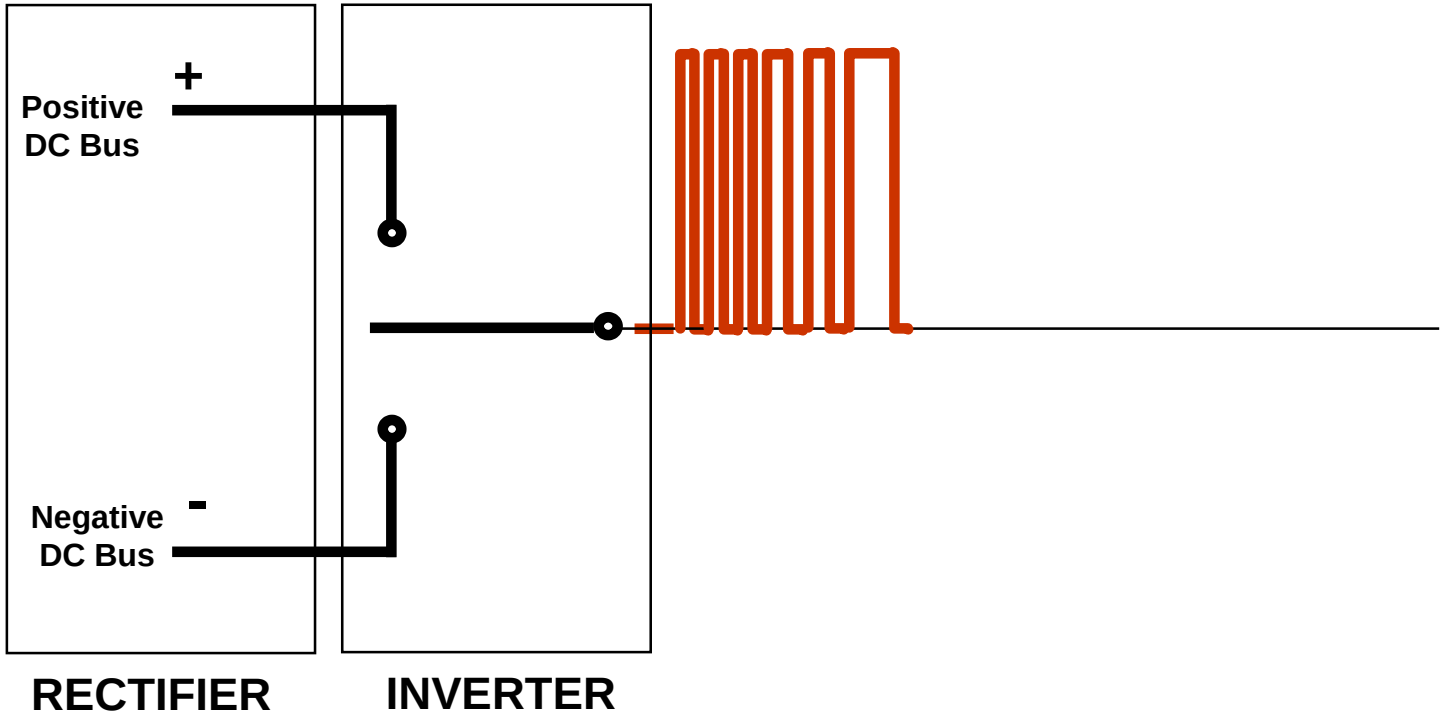
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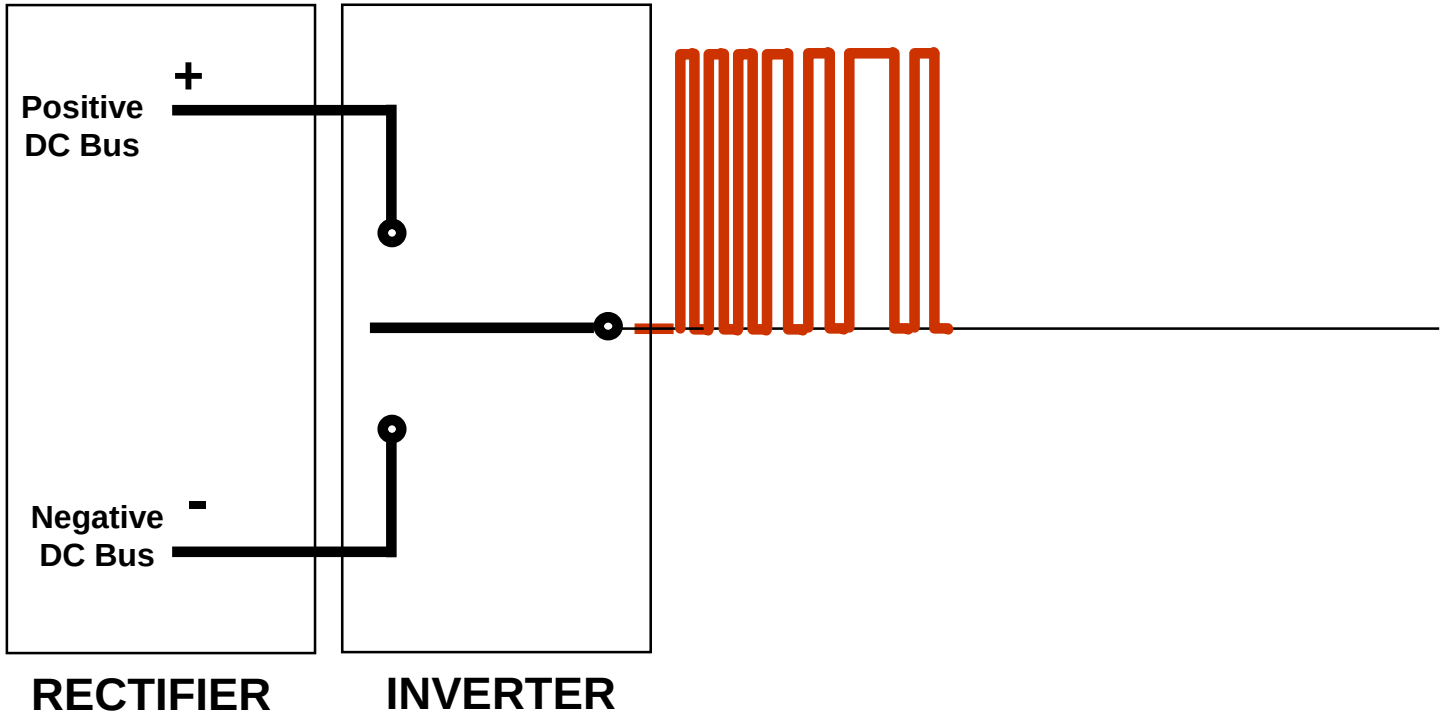
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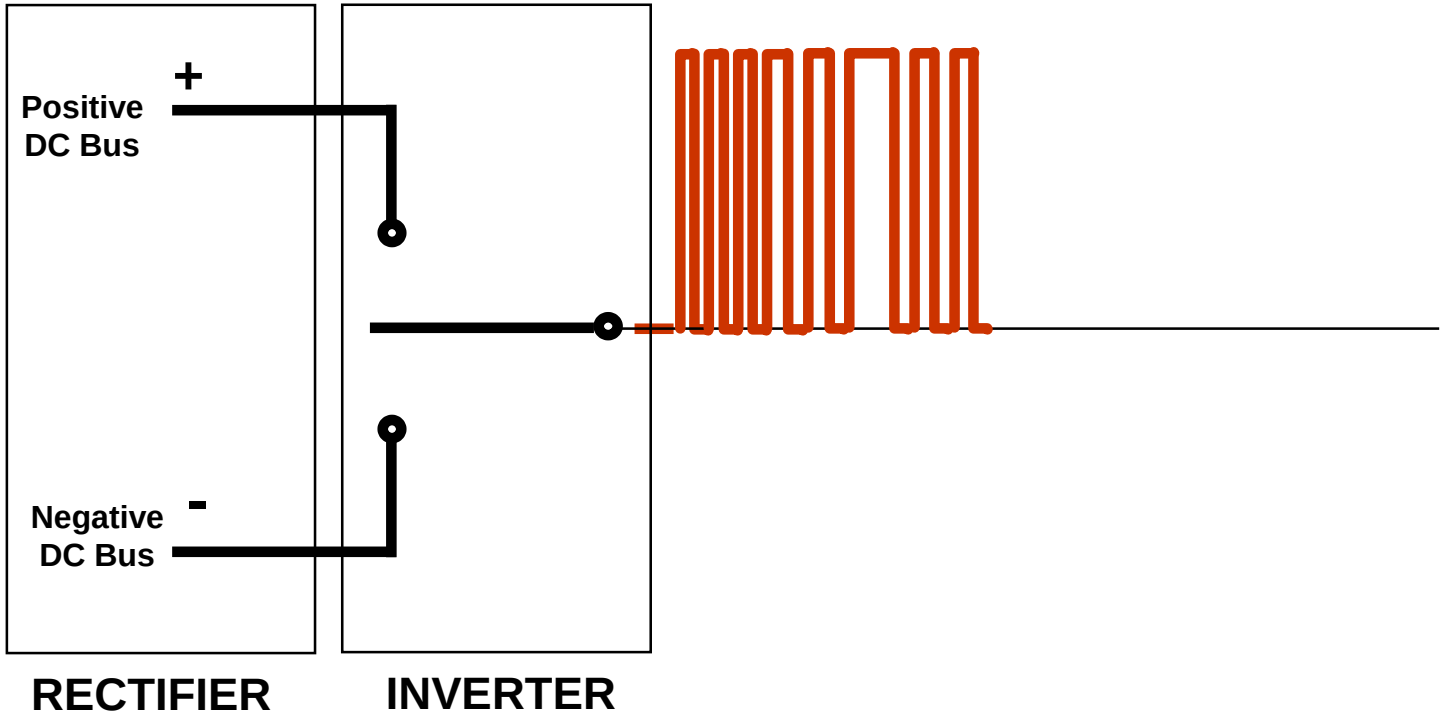
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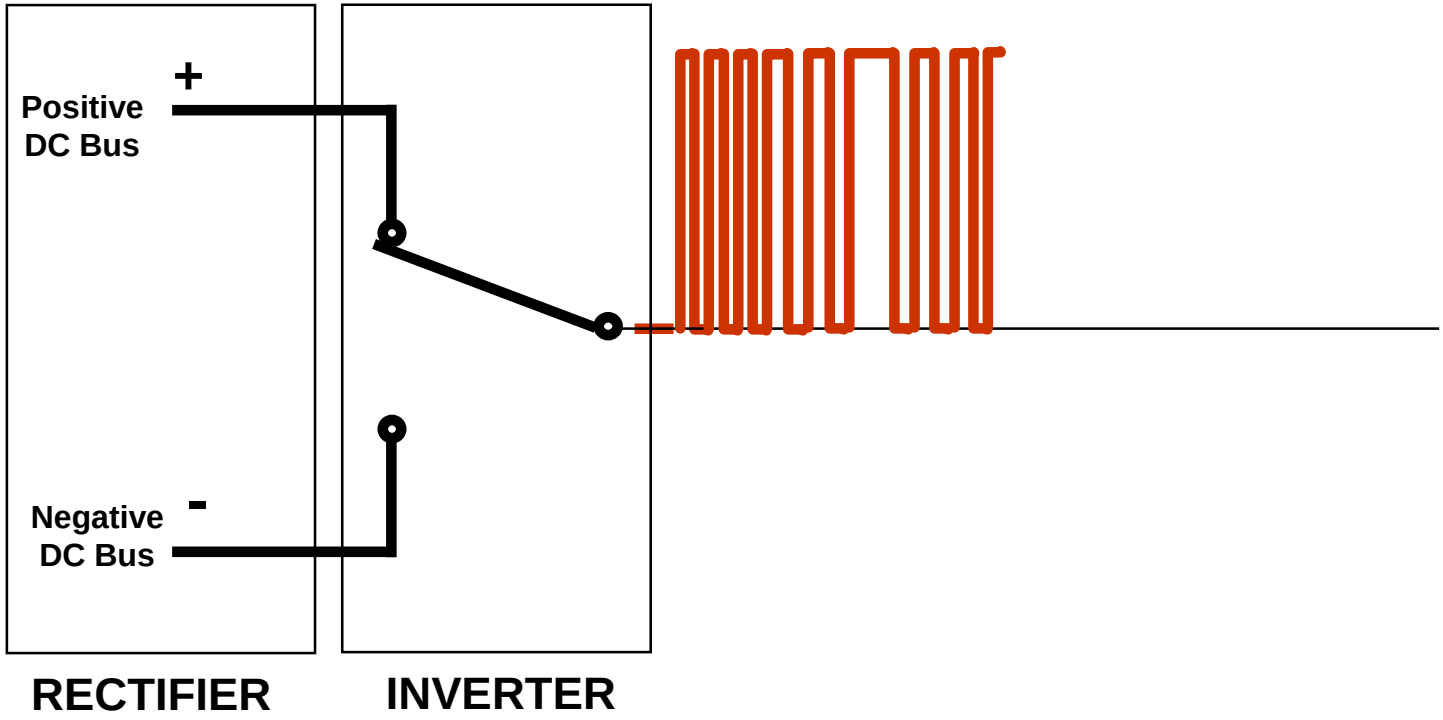
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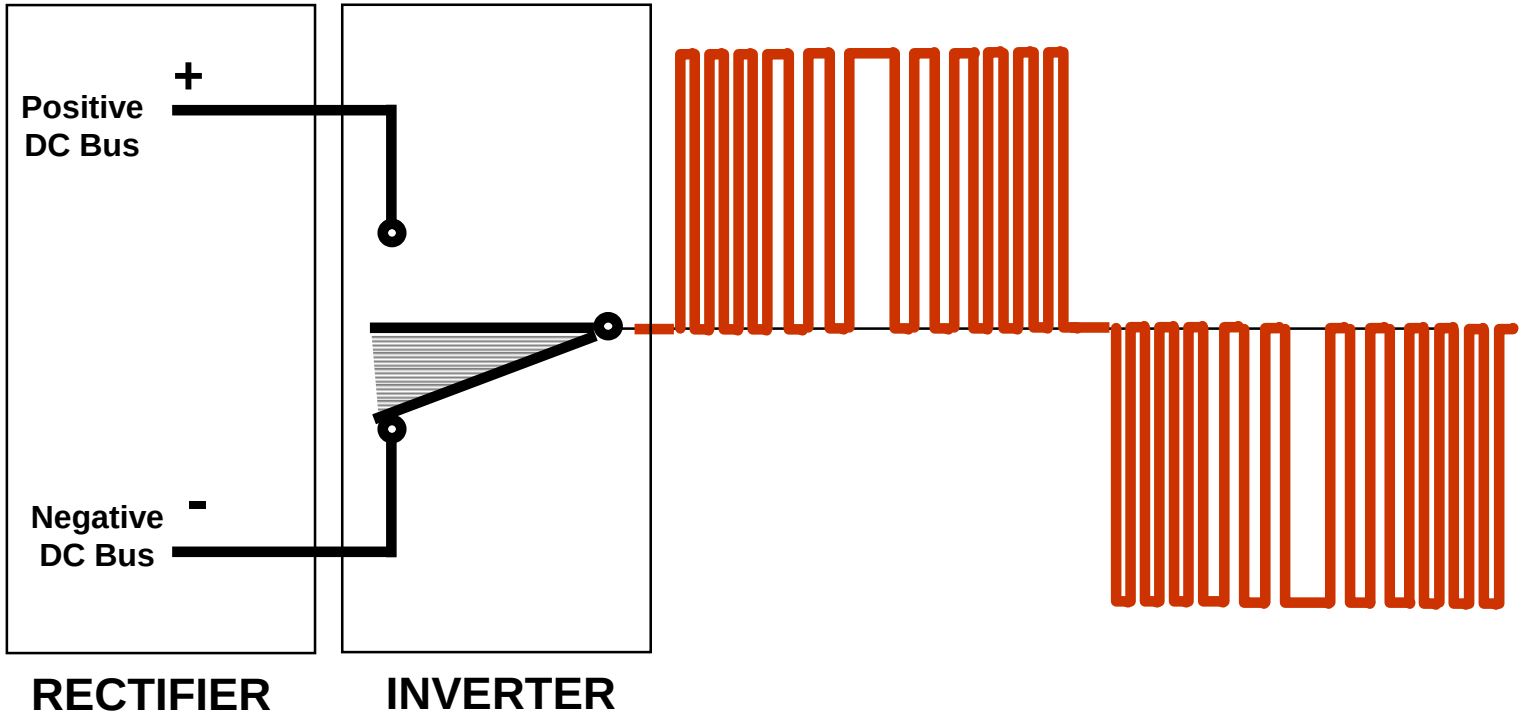
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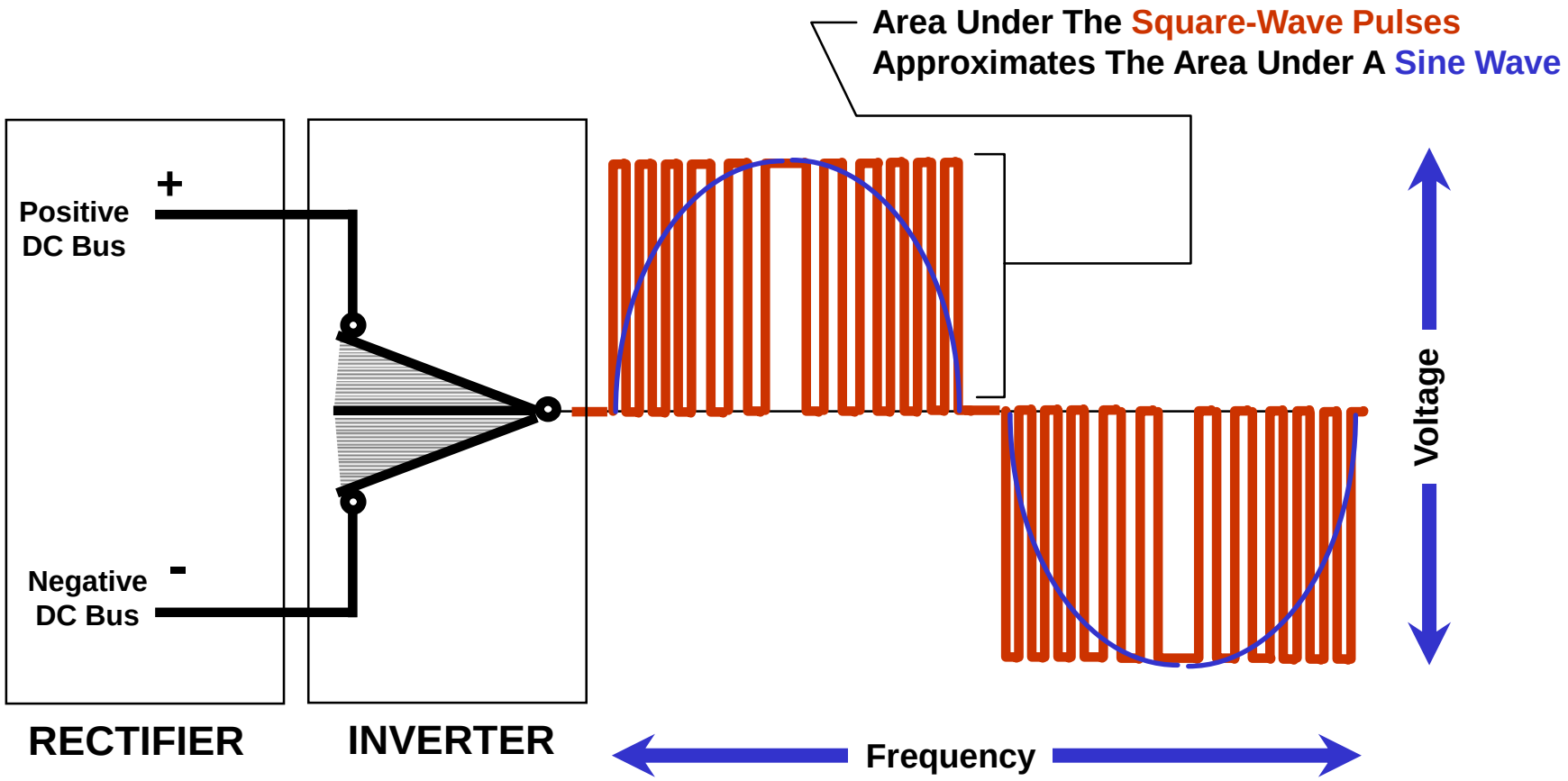
Area Under The Square-Wave Pulses
Approximates The Area Under A Sine Wave
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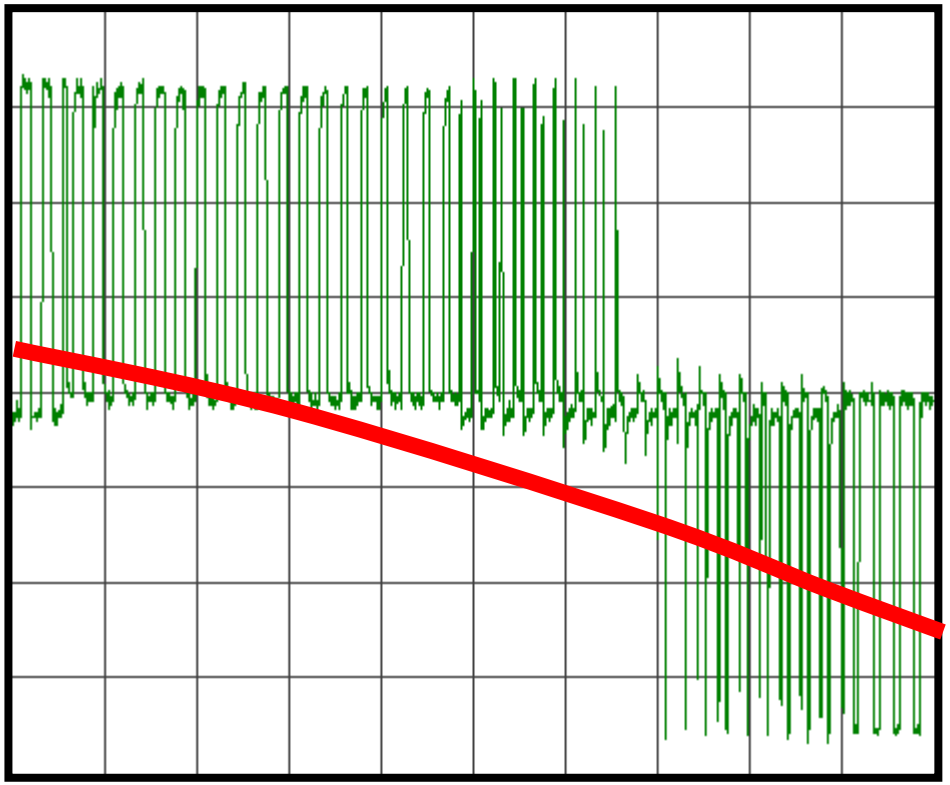
INVERTER
Frequency
Voltage

Fundamentals of Variable Frequency Drives

Pulse Width Modulation (PWM)



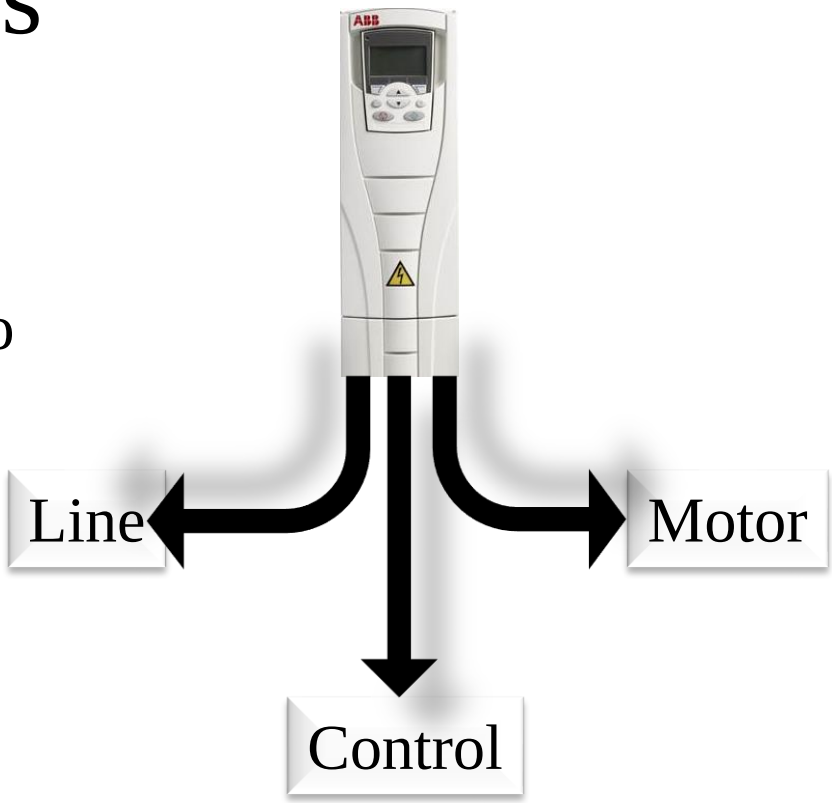
High Frequency, Motor Noise and Stress (2-20Khz)

VFD Types

Micro Drives – Small, cost reduced, **no harmonic filters**, no on-site warranty, short lifespan
Standard Drives – Robust, high volume, standard harmonic filters, on-site warranty, long life
Performance Drives – Capable, tight motor control, PLC type functions, robust, harmonic filters, long life

Avoid Problems with Good Wiring Practices

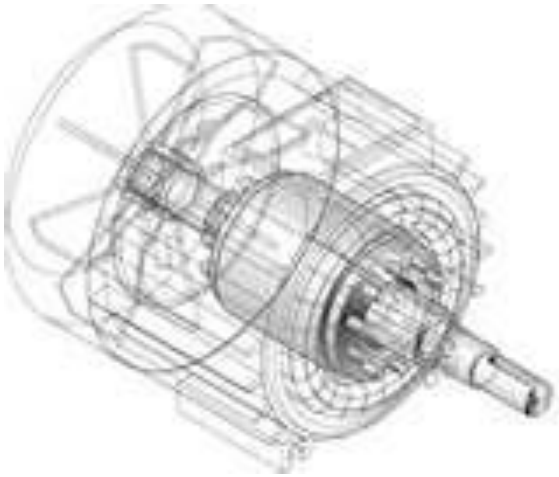
- **Motor wires**
  - Separate metal conduit
  - High strand count wire
  - Dedicated ground from motor to VFD chassis
- **Line wires**
  - Separate metal conduit
  - Ground from VFD chassis to main ground bus
- **Control wires**
  - Separate metal conduit




02.19.2009

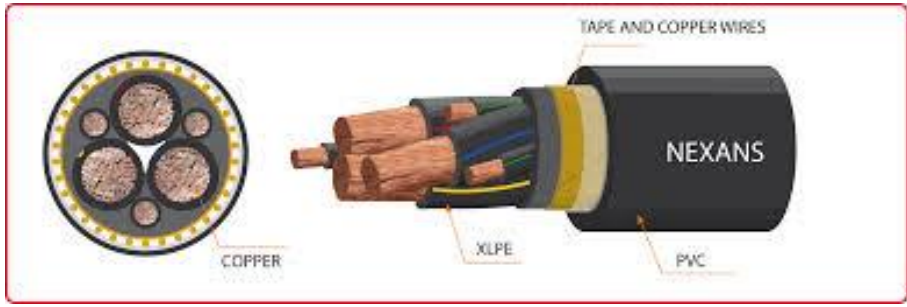
VFD Installation

- Motor – VFD compatibility (long cable runs). **NEMA MG1, Part 31** compliance & shaft grounding
- Size the VFD by the motor(s) FLA, not HP
- Size feeders per the input current of the VFD, not the motor FLA

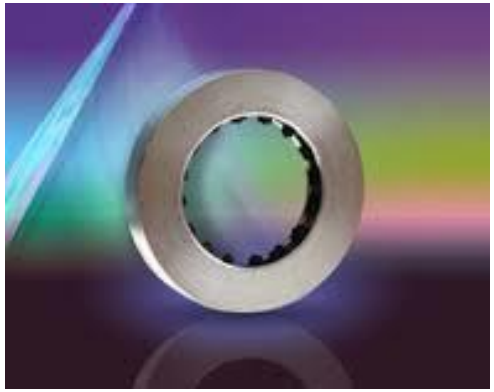


VFD Installation

- Motor – VFD cable
  - Liability reducer for the Mfg
  - Use is non-conduit installations



- Shaft grounding
  - Conductive ring
  - Carbon brush

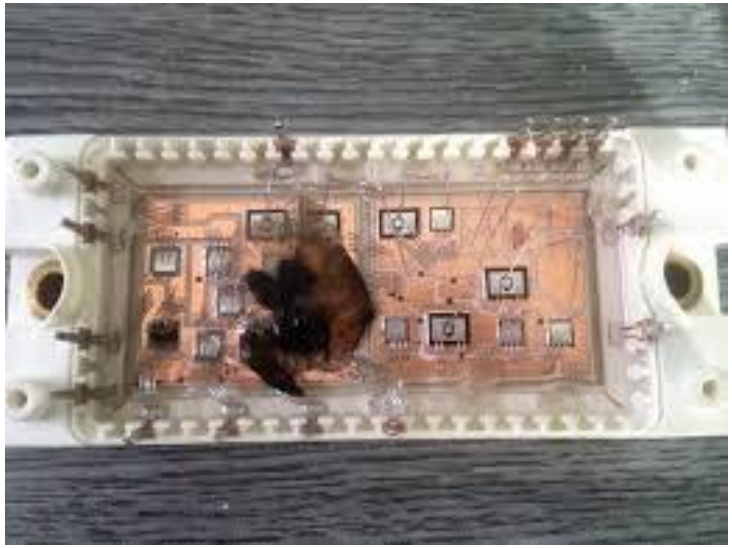


VFD Fuses?

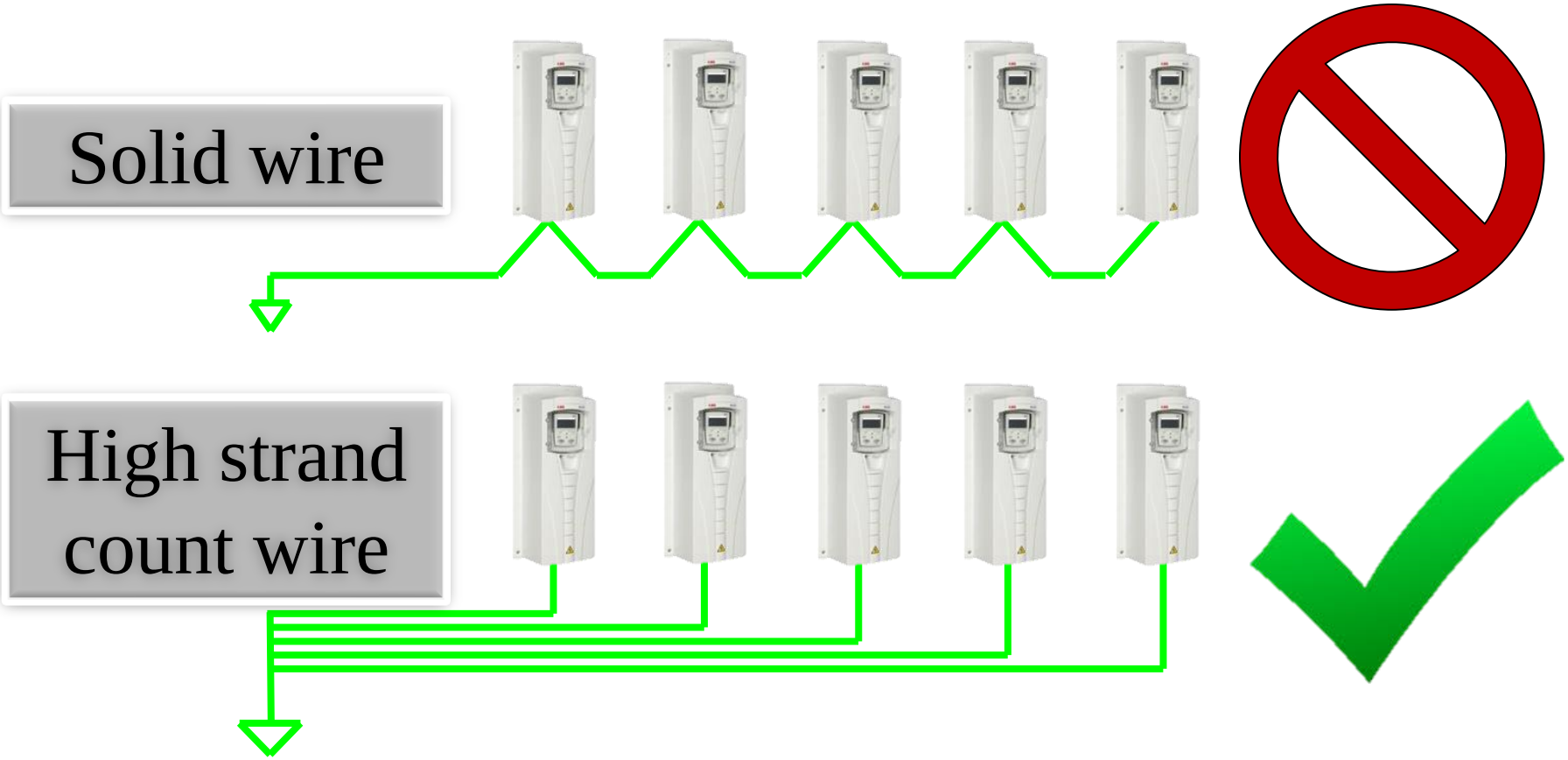
- New UL 61800-5-1 Standard changes test requirements (SCCR ratings also)
- Circuit breakers are too slow
- Bigger problem the larger the VFD
- Fast acting (class T)

I need spare fuses

- If a power fuses clears, the power structure likely failed
- The most common mode is a phase to phase short
- Do NOT replace and re-power!



Avoid Problems with Proper Grounding



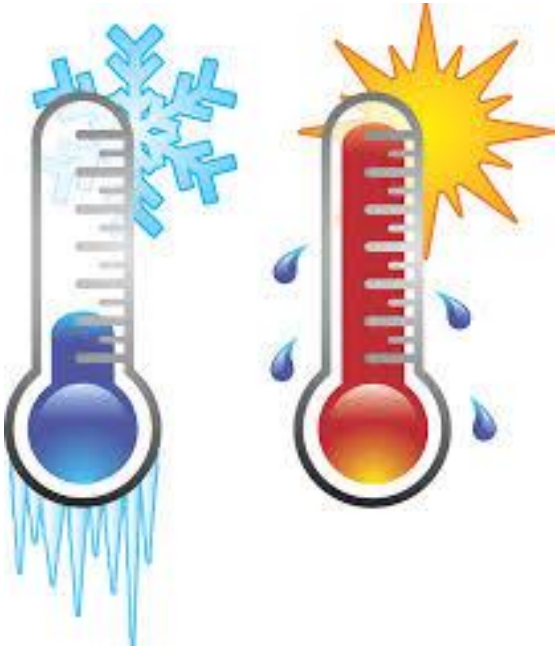
Power source to VFD, VFD to motor

Surge / Transient Protection

- Protection from AC line transients is important
- Generator testing
- Switching power factor caps
- Indirect lightning
- Some VFD’s include a standard TVSS system, some do not. Protection should be phase to phase and phase to ground. Extra attention to corner grounded systems (corner grounded delta, floating or resistant grounded systems)

VFD Installations - Ambient

- Most drives are rated 0-40C (104F)
  - Derating required for higher temps (for 50C). Large impact on drive lifespan.
  - Heaters required for cold temperatures
  - Corrosive environments
    - Conformal coating for PCB's



A 3” conduit from supply air provided “cooling air”

VFD’s are “stacked”. Heat from bottom VFD’s blow into the top row.

Maybe 20 CFM of airflow when 750 CFM min. is required. Very expensive to fix

No harmonic considerations

VFD Options

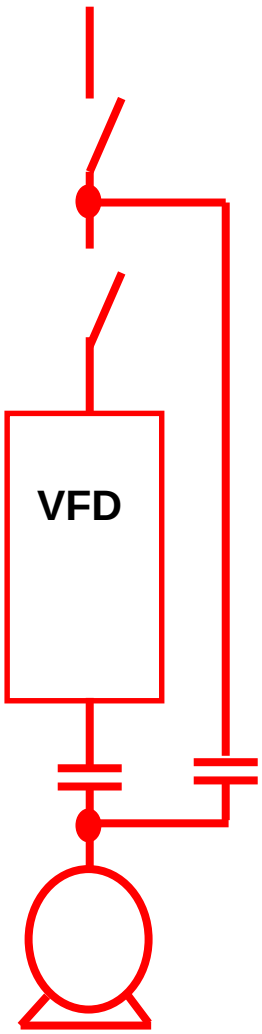
ABB ACH550: VFD Electrical One-Line

Disconnect device

- Door interlocked, padlockable
- Disconnect/fuses
- Circuit breaker
- Act as code required motor disconnect
  - Direct line of sight
  - 50’ from the motor

Bypass

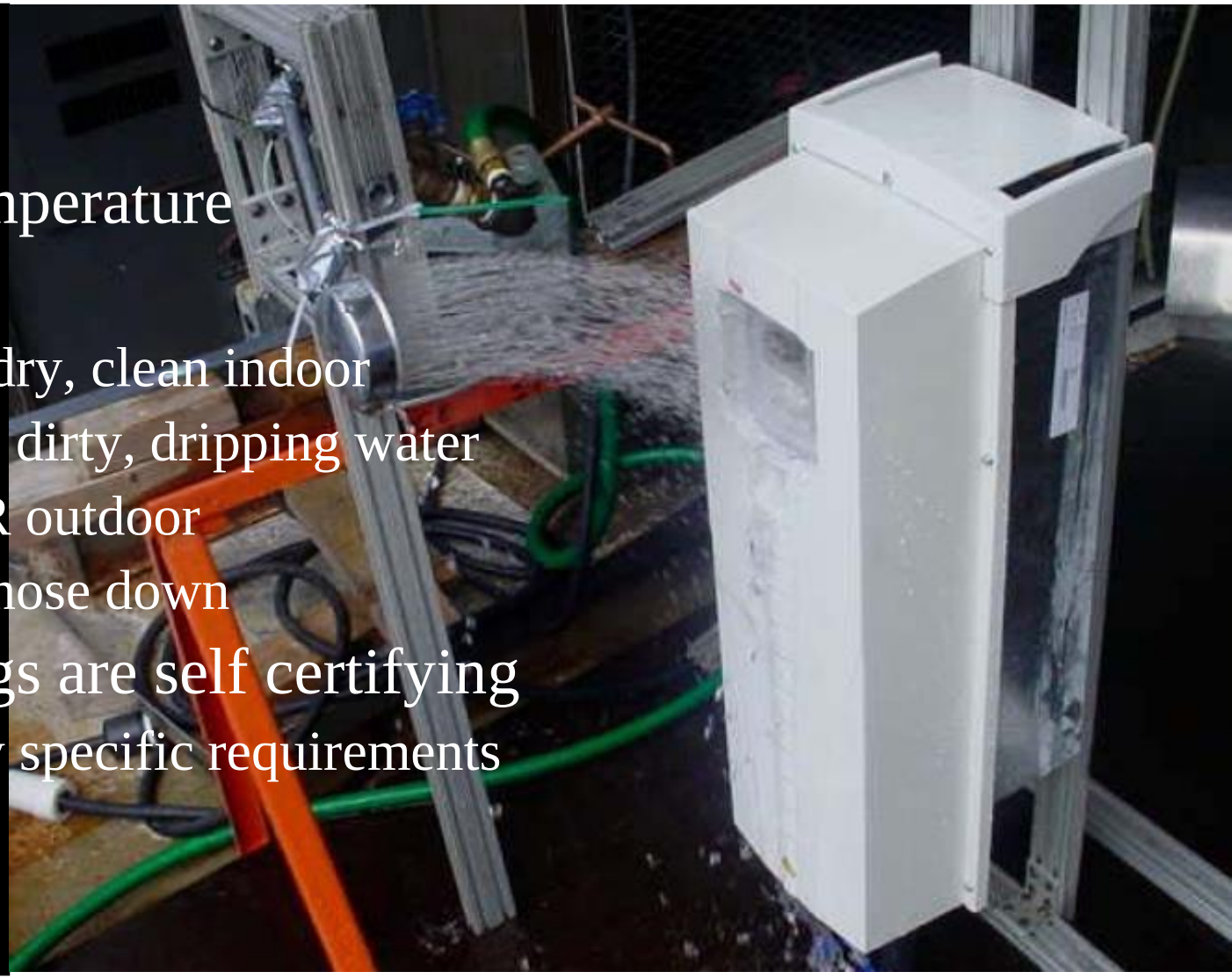
- Constant speed system if VFD fails
  - Across the line
  - Soft starter
- Redundant VFD



Redundant VFD’s

- Lead / Lag system
  - Lag VFD starts automatically if lead fails
  - Lead can be manually or remotely selected
  - Allow variable speed back-up

Enclosures Types



- Ambient Temperature
- UL rated
  - UL Type 1 dry, clean indoor
  - UL Type 12 dirty, dripping water
  - UL Type 3R outdoor
  - UL Type 4 hose down
- NEMA ratings are self certifying
  - UL has very specific requirements


HVAC

Proper enclosure selection can save money!

Enclosure need to be engineered!

UL Type-1 Rated VFD

- Indoor use
- Clean dry environment
- Good locations:
  - Dry and clean mechanical rooms
  - Some place you would keep your computer and have lunch
  - Humidity controlled
- Vast majority of drives installed in HVAC applications are Type-1

UL Type-12 Rated VFD

- Indoor use
- Moderately dirty and wet environment
- Good for:
  - RTUs
  - Damp areas / light water
  - Exposed to outside air (not weather)
  - Dirt / dust

UL Type-3R Rated VFD

- For outdoor use
- Provides a degree of protection from:
  - Falling dirt
  - Rain, sleet & snow
  - Sun exposure
- Good for mounting on Roof tops
- Includes heaters for Wisconsin winters!

Interfacing with BAS

- Monitoring / Monitoring & Control
  - Don’t waste your connection!
    - S/S, Speed, Run & Fault
    - VFD temperature, trip ID, trip reset (remote), load “health” (plugged pump, stuck valve, etc), man-auto control, KWH and much more!

Should I stock spare VFD's?

- The capacitors in VFD's have a shelf life of about 3 years
- The VFD should be powered for 24hours (no motor connected)
- Does not have to be connected to a motor