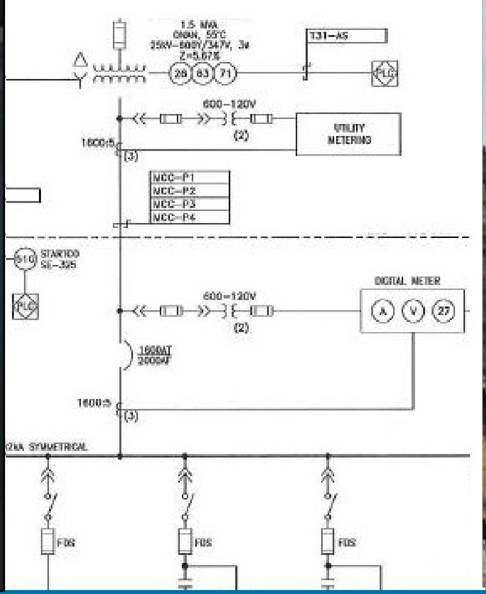


ESTMP 2016 – Edmonton, Alberta

ASDs and Reflected Waves – A review of problems and solutions

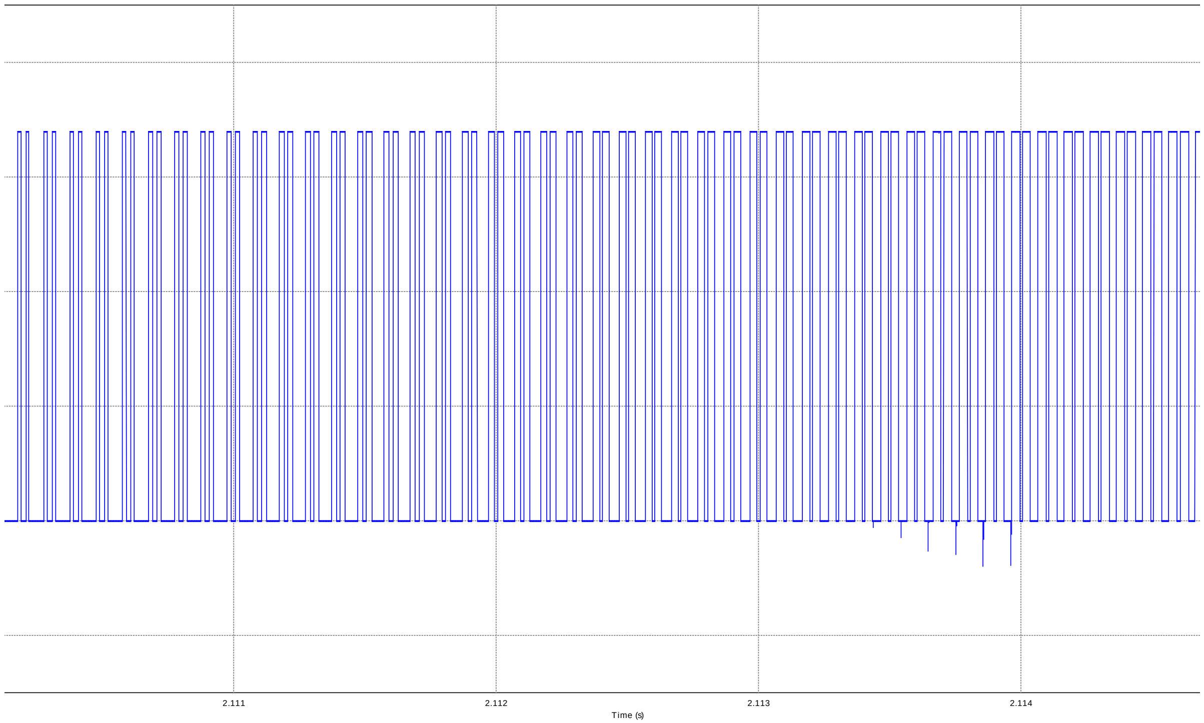
Dale Tardiff

Outline

- What is the problem?
- Possible solutions
- Comparison of solutions
- Conclusions

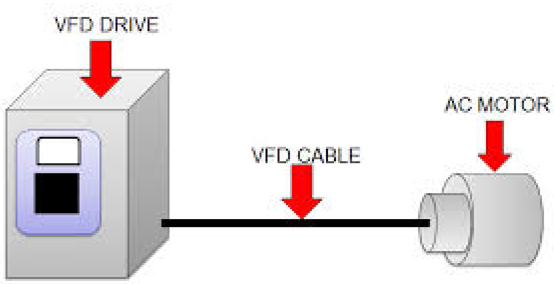
What is the problem?

What causes Reflected Waves?



- Typical PWM Drive Output Voltage – Drive End

What causes Reflected Waves?



- $V_{motor} = (1 + \Gamma) \times V_{drive}$
- Reflection:
- $\Gamma = \frac{Z_{motor} - Z_0}{Z_{motor} + Z_0}$
- Cable critical length:
- $l_c = \frac{1}{4} \cdot \pi \cdot c \cdot t_{rise}$

What causes Reflected Waves?

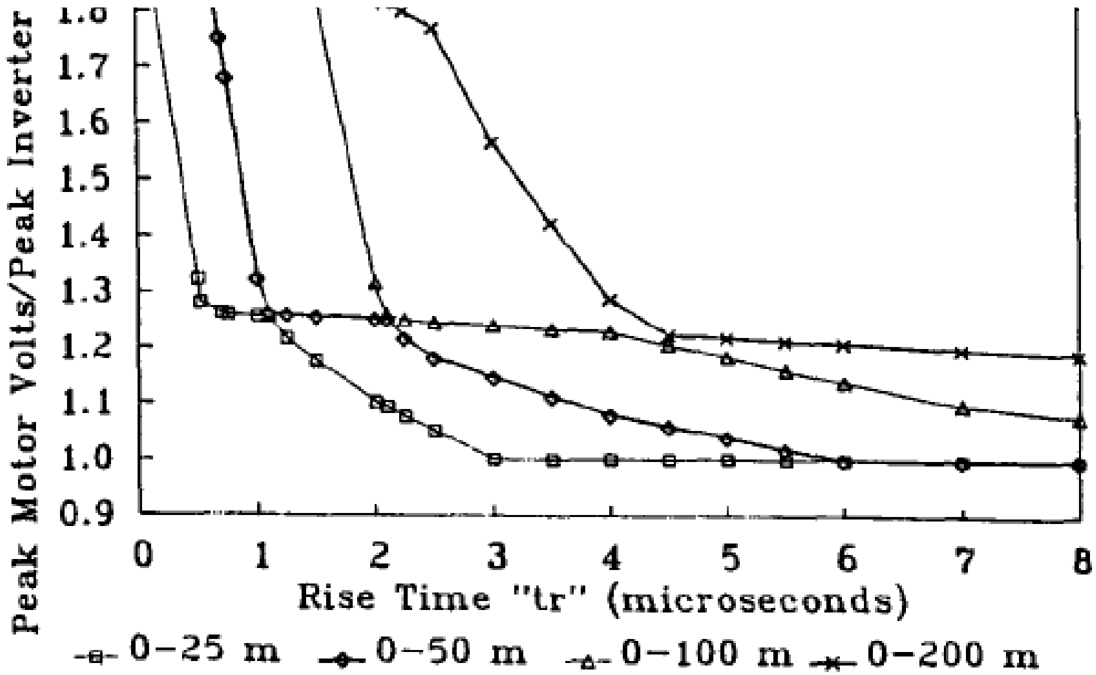
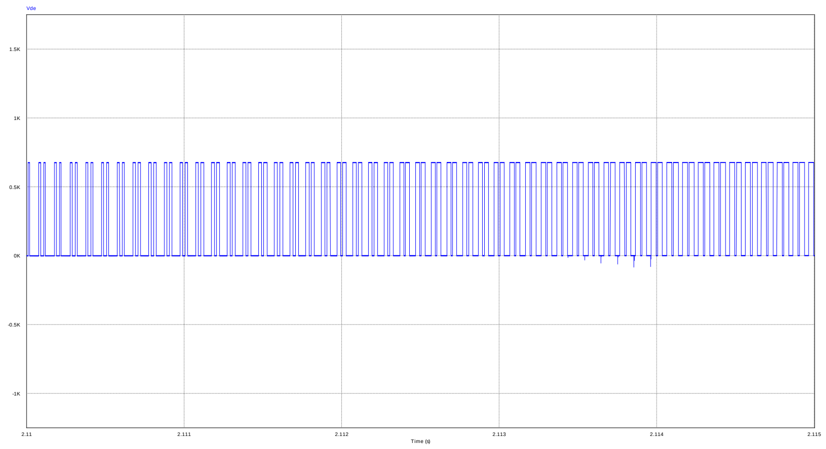


Fig. 7: Vm/Vi vs tr, where rm=0.9, ri=−1 and v=150 for various cable lengths.

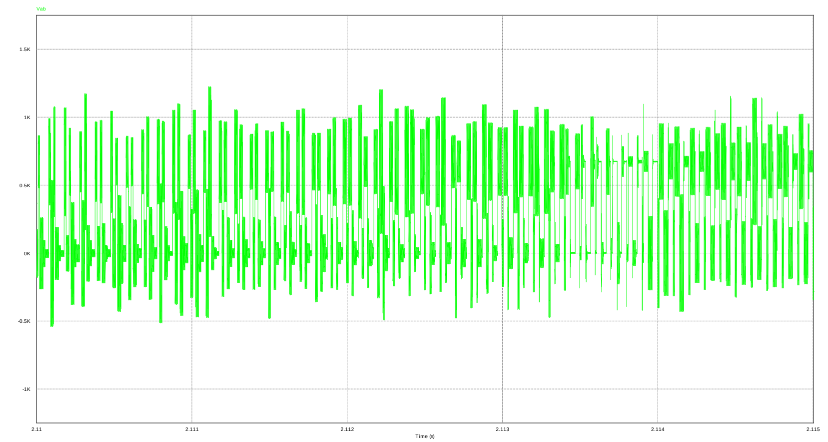
- Erik Persson, “Transient Effects in Application of PWM Inverters to Induction Motors”

What causes Reflected Waves?

Drive End Voltage

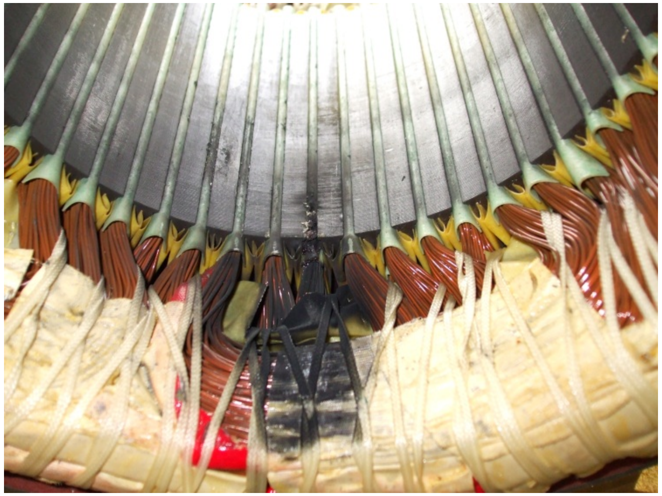


Motor End Voltage

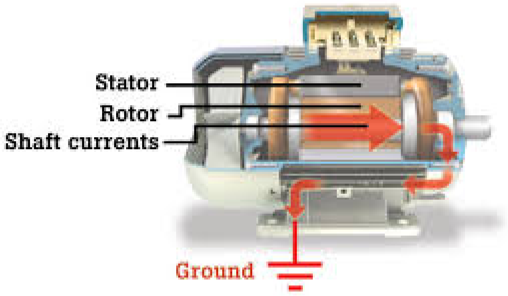


Effects of Reflected Waves

Insulation Breakdown



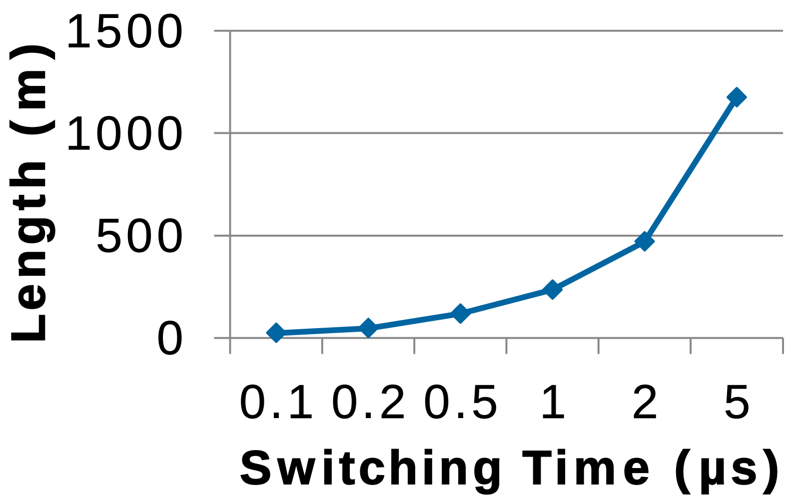
Stray dv/dt current



Why do they keep coming back?

Faster Switching Devices

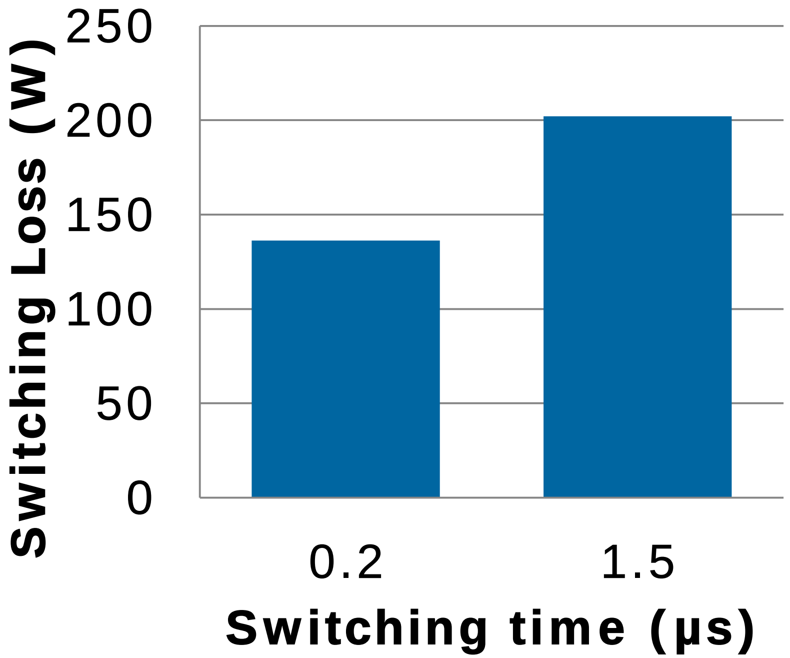
Cable Critical Length



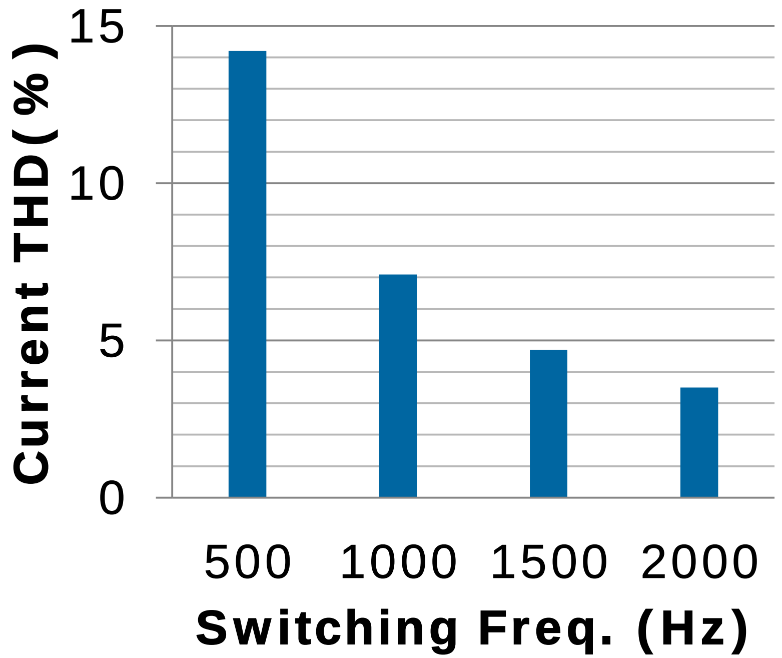
Increasing Cable Length

Why do drives use fast switching?

Reduce switching losses



Reduce harmonics



Is the problem always reflected waves?

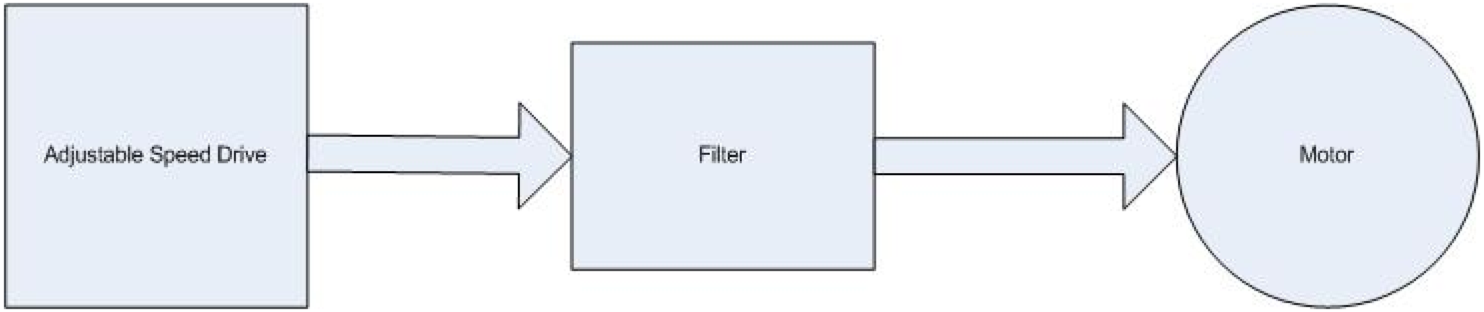
- **Harmonics can be significant**
- Rule of thumb: < 10% THD of motor current
- If motor is in a high temperature or low ventilation application, THD restrictions may be more severe.
- Voltage harmonics also have an impact, even if current harmonics are low.

Solutions

Ideal Solution

- Drive End Voltage = Motor Voltage
- No voltage overshoot at the motor
- Low harmonic content
- Motor current = drive current
- Zero or minimal additional cost
- Reliability is maintained or improved
- Additional components are readily available
- No increase in size/weight of complete motor and drive system

Filtering



- Filter can be at drive end or motor end

Filters

- Voltage drop if series filter
- Will reduce harmonics, often significantly
- Motor current could deviate from drive current
- Filter may be a significant cost factor.
- Engineering design required to ensure filter is not the weak point
- Filter components add size, and require system engineering
- Filters can be drive end or motor end

Voltage Clamp/Line Termination

Voltage Clamp/Line Termination

- Drive End Voltage = Motor Voltage
- Voltage overshoot may not be 100% eliminated
- Little or no impact on harmonics
- Motor current could deviate from drive current
- Cost lower than some other solutions
- Possible reliability issues
- May need system engineering or long delivery components
- Must be at the motor end

Upgraded cables

- Drive End Voltage = Motor Voltage?
- May not necessarily eliminate motor overshoot
- Cable cost may increase, possibly significantly
- Can the enhanced cable be used in your environment?

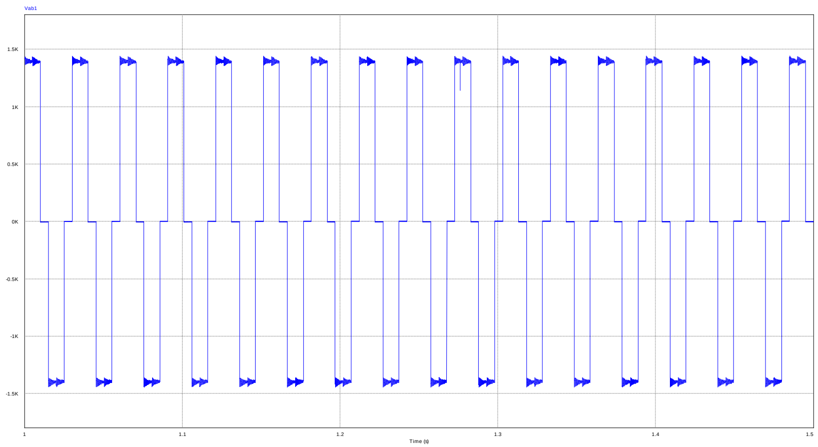
- Does not improve harmonics
- Motor current = drive current
- Cable delivery - TBD
- No increase in size/weight of complete motor and drive system

Upgraded Motor

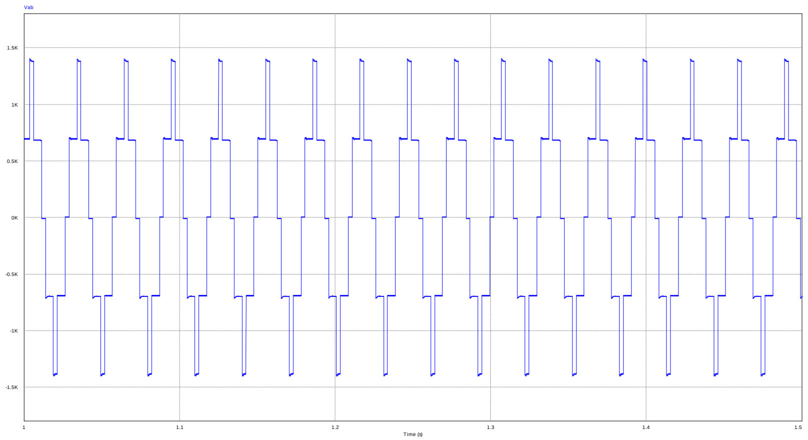
- Drive End Voltage = Motor Voltage
- Does not eliminate overshoots, merely survives.
- Does not improve harmonics
- Motor current = drive current
- Motor cost will increase, possibly significantly
- Motor delivery - TBD
- Motor size will likely increase

Drive Topology – Multi-level Drive

2 level Voltage



3 level Voltage



Drive Topology – Multi-level drive

- Drive End Voltage = Motor Voltage
- Reduced voltage overshoot at the motor
- Reduces harmonics
- Motor current = drive current
- Cost not necessarily higher than equivalent 2 level solution.
- Reliability may be lower, but not significantly
- Delivery time - TBD
- No increase in size/weight of complete motor and drive system

Comparing Strategies

Comparison of Techniques

Method	V @ mot	THD	Cost	Reliability	Size	Loc
Filters	≠ drive	improve	\$\$\$	TBD	↑	both
Termination	NC	??	\$\$	TBD	↑	motor
Upgrade cable	NC	NC	\$\$	TBD	NC	cable
Upgrade motor	NC	NC	\$\$	TBD	↑	motor
Multilevel drive	NC	improve	\$	TBD	?	drive

Conclusions

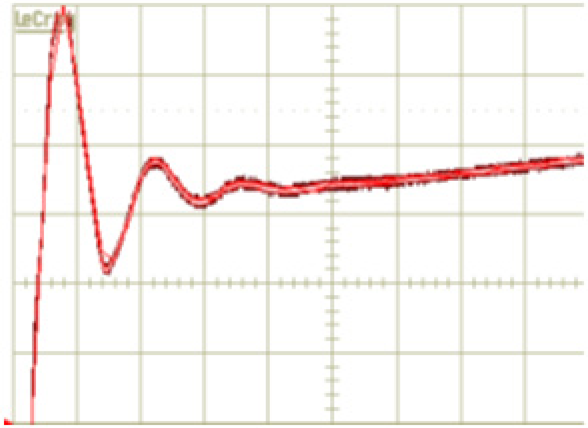
Conclusions

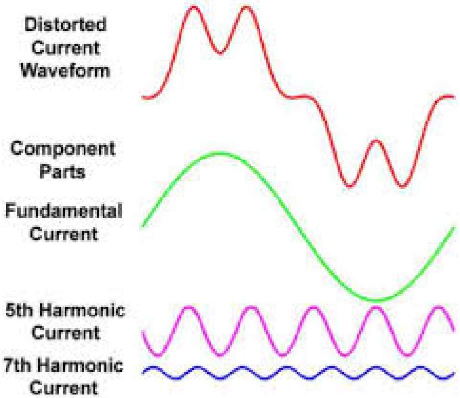
Reduce size, THD, losses → Need faster devices → Voltage reflection more common

- Combination of faster devices and longer cables will cause issue to re-occur

Conclusions

- Both voltage overshoots and harmonics are issues that can cause premature motor failures





Conclusions

- Do the engineering needed to determine your optimum solution:
- Each method has different impacts on cost, reliability and system performance.