Switched Capacitive Filter for Harmonic Suppression in Variable Speed Induction Motor Drive

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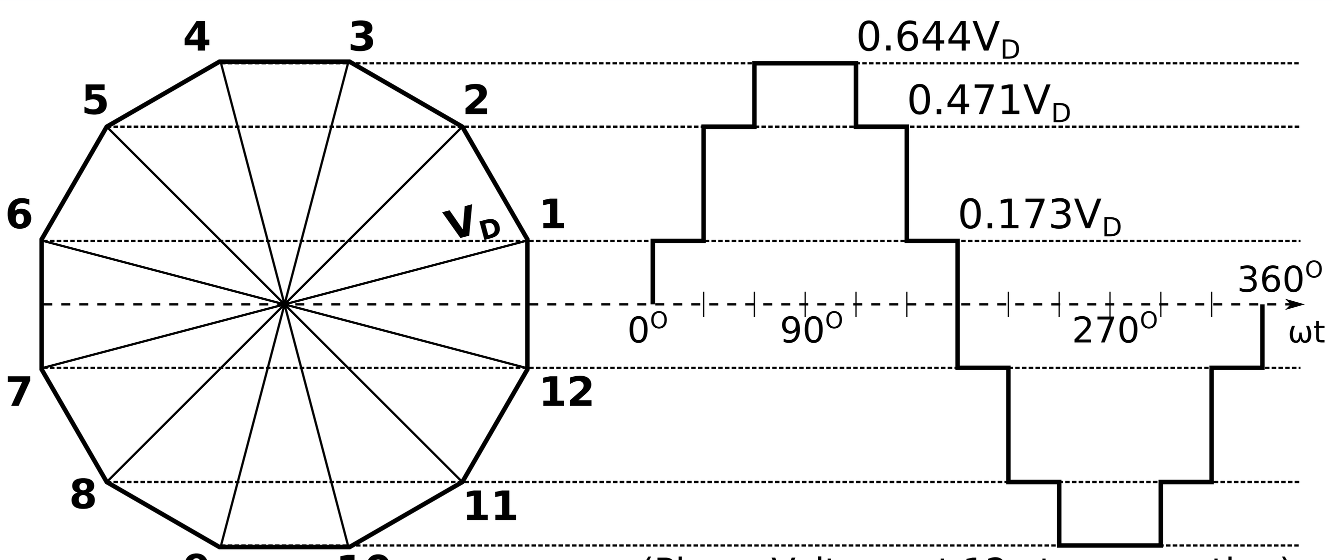
Abstract

A novel switched capacitive filter is proposed to eliminate 5th and 7th order harmonics from the phase voltage of conventional two-level inverter. Dodecagonal voltage space vector is implemented using a single DC supply. A switching technique is proposed which pre-charges the capacitor and controls its voltage while simultaneously eliminating 5th and 7th order harmonics from the phase voltage. It is shown that the higher switching frequency is shifted to low voltage switches, thus reducing the switching loss compared to conventional two-level inverter where high switching frequency is used for harmonic suppression.

5th & 7th Order Harmonic Elimination



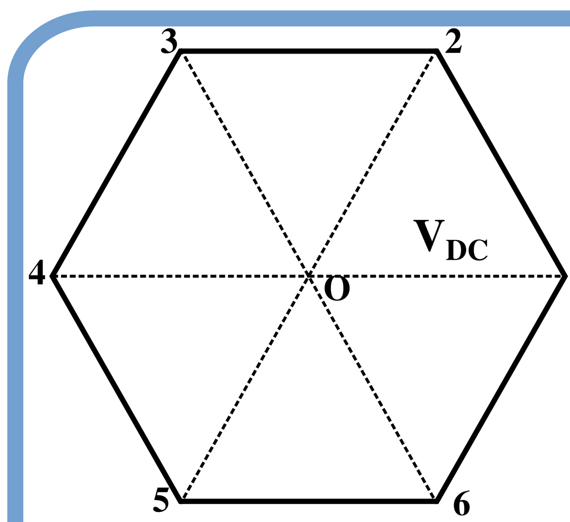
(Phase Voltage at 12-step operation)

$$V_{phase,n} = \frac{4}{\pi}\int_0^{\frac{\pi}{2}} V_{phase}\sin(n\omega t)d\omega t$$

$$V_{phase,n} = \frac{4V_d}{n\pi}\left[0.173 + 0.298\cos(\frac{n\pi}{6}) + 0.173\cos(\frac{n\pi}{3})\right]$$

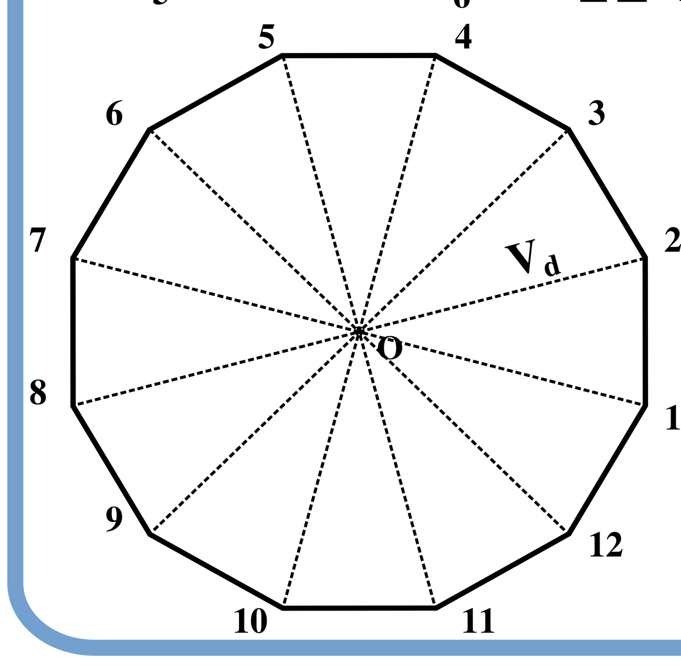
$$V_{phase,1} = 0.659V_d; V = V_{phase,7} = V_{phase,17} = V_{phase,19} = 0$$

Zero Active Power Contribution



Peak fundamental voltage for six step operation=**$0.637V_{DC}$**

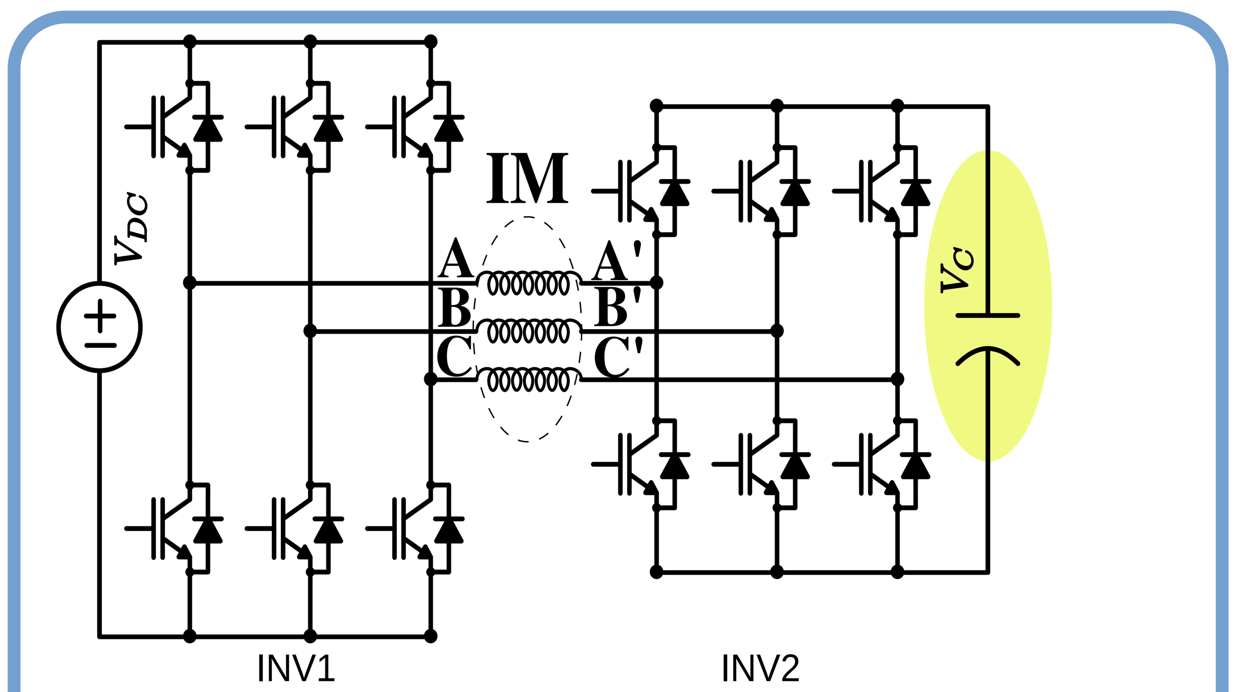
Peak fundamental voltage for 12-step operation=**$0.659V_d$**



Equal phase voltage ensures equal active power generation

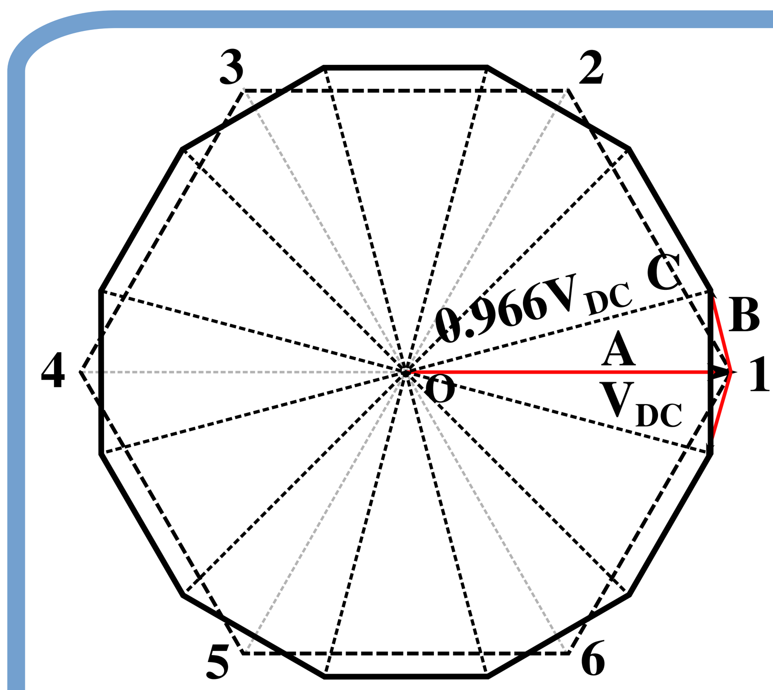
V_d=0.966V_{DC}

Power Circuit

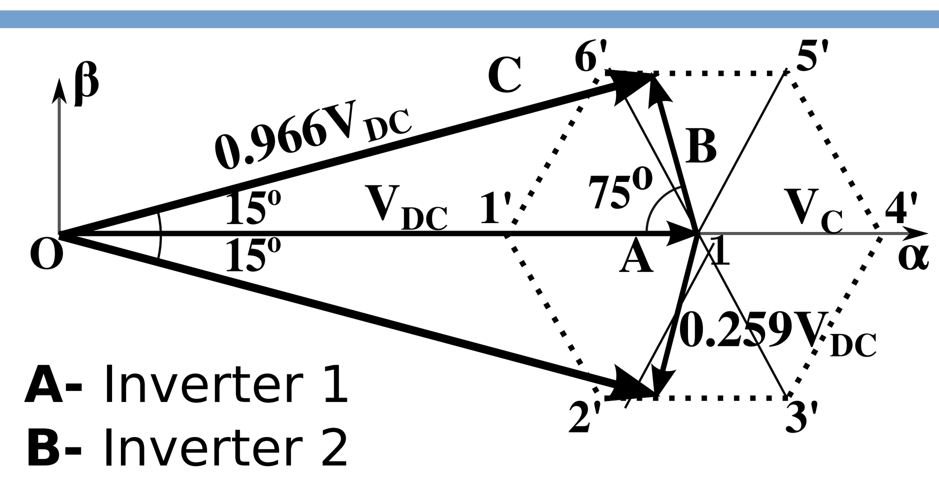


- DC supply of secondary inverter substituted by capacitor
- No active power contribution from secondary inverter

Vector Construction



16' kT_1 + **15'** $(1-k)T_1$ = **B** T_1
⇒ $V_C\angle{-60^\circ}\, kT_1 + V_C\angle{60^\circ}\,(1-k)T_1 = 0.259V_{DC}\angle{-75^\circ}\, T_1$ (1)
Resolving Eq. 1 in α-β axes:
V_C=0.289V_{DC}
k=0.732



A- Inverter 1
B- Inverter 2

Extreme point in linear modulation range

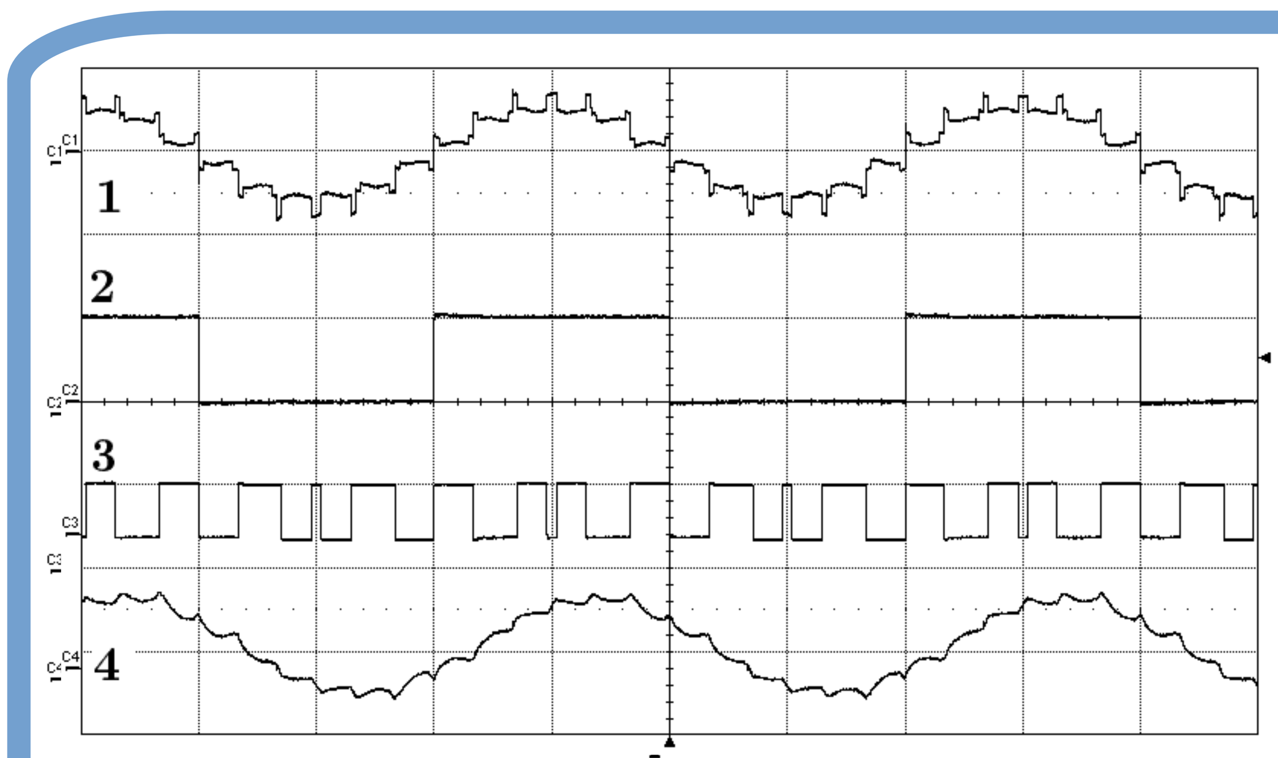
$V_{phase,pk}$=(2/3)(0.966V_{DC}cos15°)=**0.622V_{DC}**

Extreme linear modulation supply frequency= **48.8Hz**

Increase in linear modulation range (%)=**7.8%**

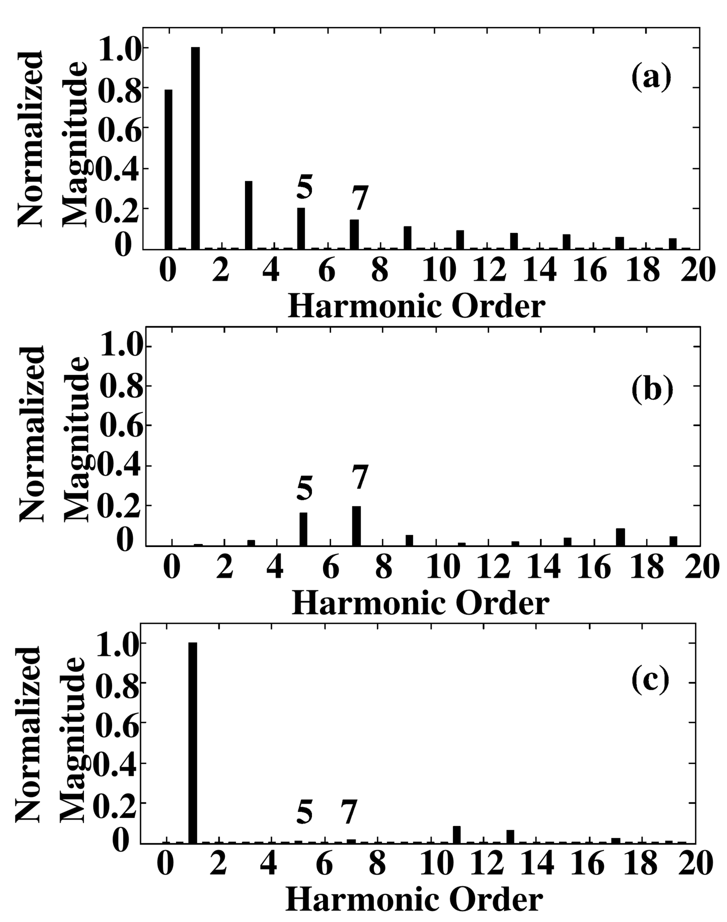
6' and **5'** have opposing effect on the capacitor voltage state. Duty ratio *k* controlled to maintain capacitor voltage

Experimental Results

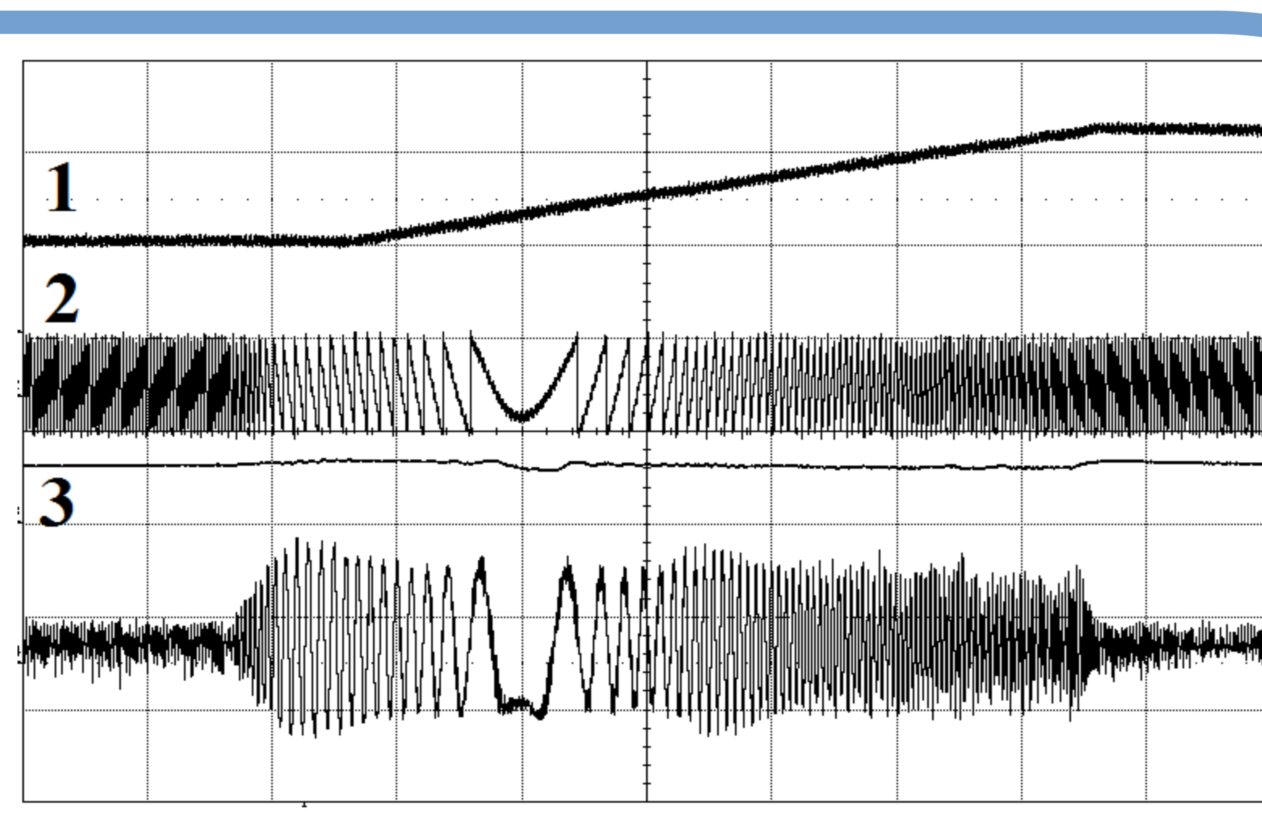


1. Phase Voltage-(200V/div), **2.** Inv-1 Pole Voltage-(200V/div)
3. Inv-2 Pole Voltage-(100V/div), **4.** Phase current-1A/div.
X-axis: 5ms/div

Steady State 50Hz Waveform



FFT Spectrum of (a) Inv-1 pole voltage, (b) Inv-2 pole voltage, (c) Machine phase voltage



1: Machine speed(2500rpm/div), 2: Rotor position(6.28rad/div)
3: Filter capacitor voltage(100V/div), 4: Phase Current(2A/div)
Timescale: 1s/div

Speed reversal from -48Hz to 48Hz with rotor field oriented vector control

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