ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF VOLTAGE SOURCE CONVERTERS

SESSION no. 16

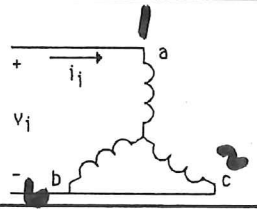
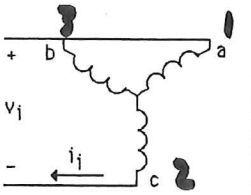
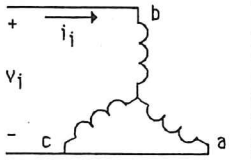
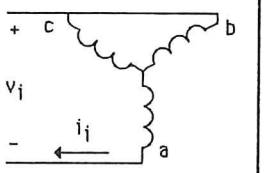
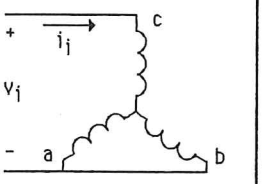
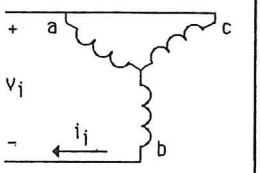
1	$-\frac{\pi}{6} < \omega_e t < \frac{\pi}{6}$		$v_{qs}^s = \frac{2}{3}v_i$ $v_{ds}^s = 0$ $i_i = i_{qs}^s$	$\underline{v}_{qds}^s = \frac{2}{3}v_i e^{j0}$
2	$\frac{\pi}{6} < \omega_e t < \frac{\pi}{2}$		$v_{qs}^s = \frac{v_i}{3}$ $v_{ds}^s = -\frac{v_i}{\sqrt{3}}$ $i_i = \frac{1}{2}i_{qs}^s - \frac{\sqrt{3}}{2}i_{ds}^s$	$\underline{v}_{qds}^s = \frac{2}{3}v_i e^{j\frac{\pi}{3}}$
3	$\frac{\pi}{2} < \omega_e t < \frac{5\pi}{6}$		$v_{qs}^s = -\frac{v_i}{3}$ $v_{ds}^s = -\frac{v_i}{\sqrt{3}}$ $i_i = -\frac{1}{2}i_{qs}^s - \frac{\sqrt{3}}{2}i_{ds}^s$	$\underline{v}_{qds}^s = \frac{2}{3}v_i e^{j\frac{2\pi}{3}}$
4	$\frac{5\pi}{6} < \omega_e t < \frac{7\pi}{6}$		$v_{qs}^s = -\frac{2}{3}v_i$ $v_{ds}^s = 0$ $i_i = -i_{qs}^s$	$\underline{v}_{qds}^s = \frac{2}{3}v_i e^{j\pi}$
5	$\frac{7\pi}{6} < \omega_e t < \frac{3\pi}{2}$		$v_{qs}^s = -\frac{v_i}{3}$ $v_{ds}^s = \frac{v_i}{\sqrt{3}}$ $i_i = -\frac{1}{2}i_{qs}^s + \frac{\sqrt{3}}{2}i_{ds}^s$	$\underline{v}_{qds}^s = \frac{2}{3}v_i e^{j\frac{4\pi}{3}}$
6	$\frac{3\pi}{2} < \omega_e t < \frac{11\pi}{6}$		$v_{qs}^s = \frac{v_i}{3}$ $v_{ds}^s = \frac{v_i}{\sqrt{3}}$ $i_i = \frac{1}{2}i_{qs}^s + \frac{\sqrt{3}}{2}i_{ds}^s$	$\underline{v}_{qds}^s = \frac{2}{3}v_i e^{j\frac{5\pi}{3}}$

Figure 3.1 *d,q* equations for the six modes of a VSI

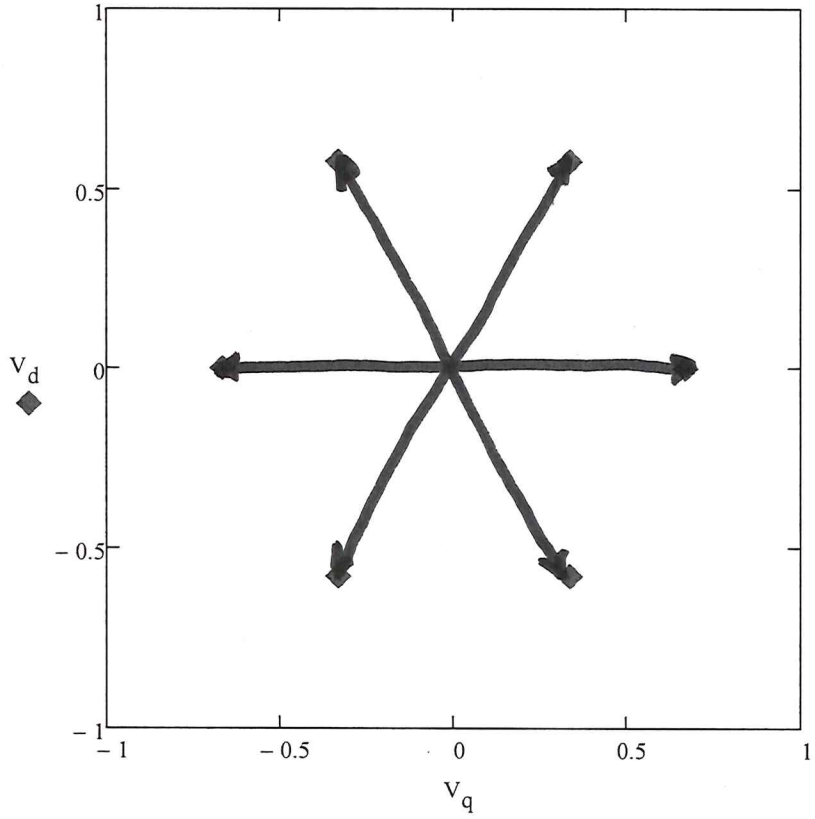
$$v_{00} = \frac{2}{3}\left[\frac{1}{2}\left(\frac{V_{dc}}{2}\right) + \frac{1}{2}\left(\frac{-V_{dc}}{2}\right) + \frac{1}{2}\left(-\frac{V_{dc}}{2}\right)\right]$$

$$v_{00} = \frac{2}{3} \cdot \frac{1}{2}\left[-\frac{V_{dc}}{2}\right]$$

$$v_{00} = -\frac{V_{dc}}{6}$$

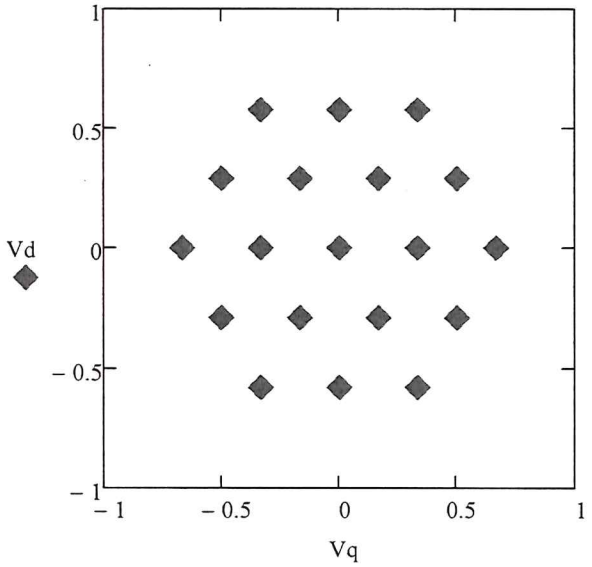
Voltage Sourced Converter: Space Vectors, Two-Level

$$V_q := \begin{pmatrix} \frac{2}{3} \\ \frac{1}{3} \\ -\frac{1}{3} \\ -\frac{2}{3} \\ -\frac{1}{3} \\ \frac{1}{3} \end{pmatrix} \qquad V_d := \begin{pmatrix} 0 \\ \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} \\ 0 \\ -\frac{1}{\sqrt{3}} \\ -\frac{1}{\sqrt{3}} \end{pmatrix}$$

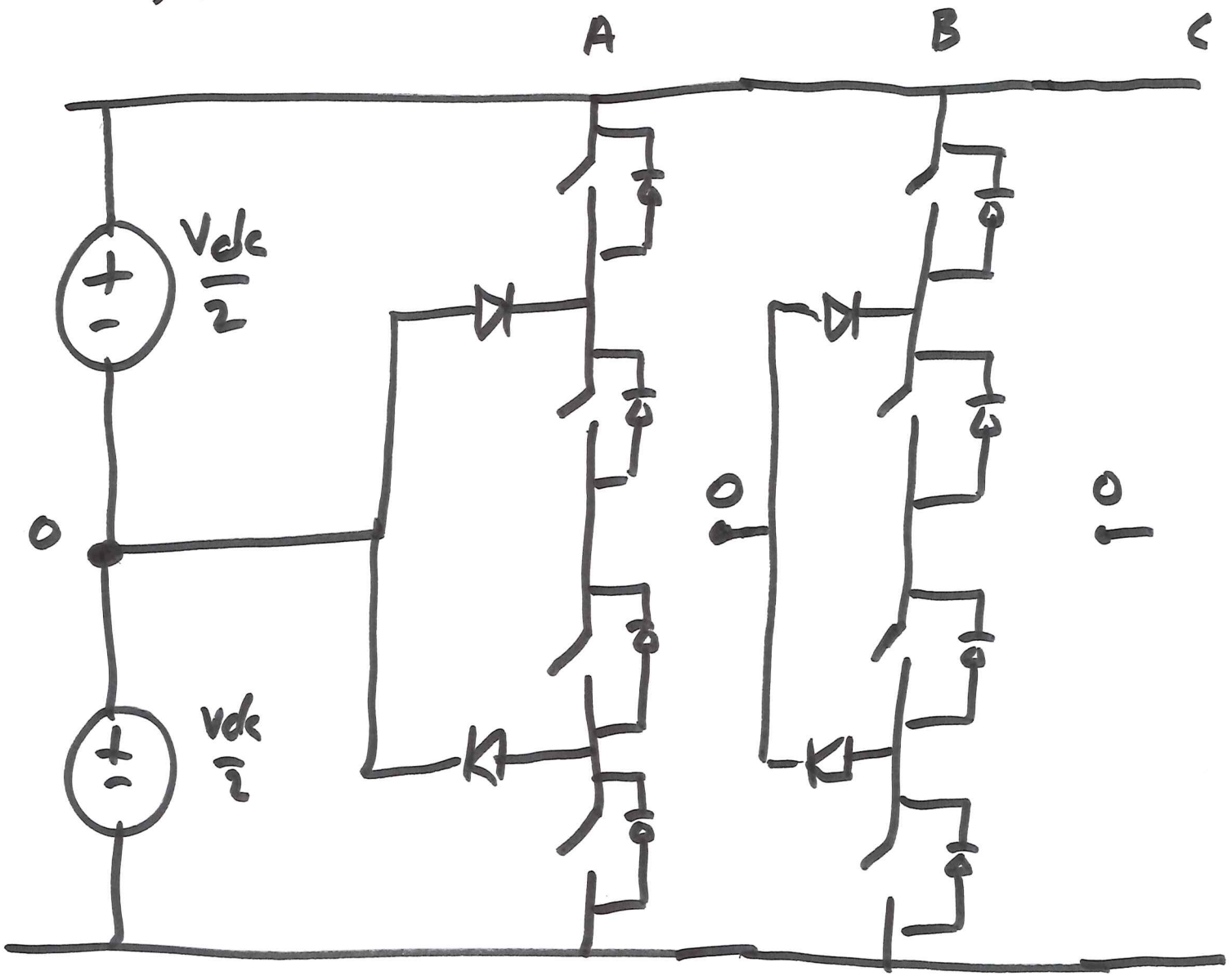


$$Vq := \begin{pmatrix} 0.666666667 \\ 0.5 \\ 0.333333333 \\ 0 \\ -0.333333333 \\ -0.5 \\ -0.666666667 \\ -0.5 \\ -0.333333333 \\ 0 \\ 0.333333333 \\ 0.5 \\ 0.333333333 \\ 0.166666667 \\ -0.166666667 \\ -0.333333333 \\ -0.166666667 \\ 0.166666667 \\ 0.333333333 \\ 0.166666667 \\ -0.166666667 \\ -0.333333333 \\ -0.166666667 \\ 0.166666667 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$Vd := \begin{pmatrix} 0 \\ -0.288675135 \\ -0.577350269 \\ -0.577350269 \\ -0.577350269 \\ -0.288675135 \\ 0 \\ 0.288675135 \\ 0.577350269 \\ 0.577350269 \\ 0.577350269 \\ 0.288675135 \\ 0 \\ -0.288675135 \\ -0.288675135 \\ 0 \\ 0.288675135 \\ 0.288675135 \\ 0 \\ -0.288675135 \\ -0.288675135 \\ 0 \\ 0.288675135 \\ 0.288675135 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$



$$\frac{V_{dc}}{2}, 0, -\frac{V_{dc}}{2}$$


A
B
C
Vdc
2
0
Vdc
2
0
0

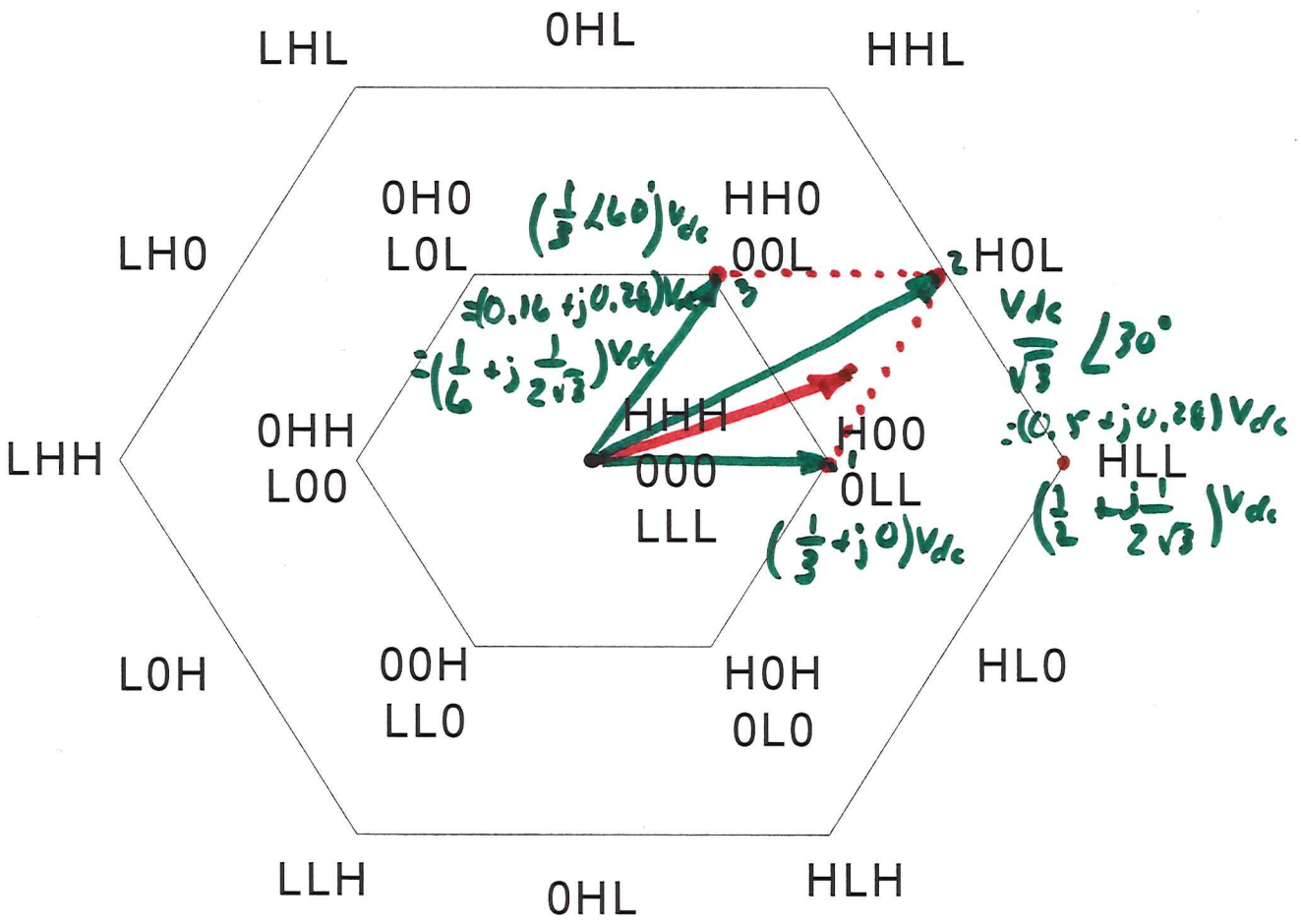
Van	Vbn	Vcn	Vqn	Vdn	Von
0.5	-0.5	-0.5	0.6666667	0	-0.3333333
0.5	0	-0.5	0.5	-0.2886751	0
0.5	0.5	-0.5	0.3333333	-0.5773503	0.3333333
0	0.5	-0.5	0	-0.5773503	0
-0.5	0.5	-0.5	-0.3333333	-0.5773503	-0.3333333
-0.5	0.5	0	-0.5	-0.2886751	0
-0.5	0.5	0.5	-0.6666667	0	0.3333333
-0.5	0	0.5	-0.5	0.2886751	0
-0.5	-0.5	0.5	-0.3333333	0.5773503	-0.3333333
0	-0.5	0.5	0	0.5773503	0
0.5	-0.5	0.5	0.3333333	0.5773503	0.3333333
0.5	-0.5	0	0.5	0.2886751	0
0	-0.5	-0.5	0.3333333	0	-0.6666667
0	0	-0.5	0.1666667	-0.2886751	-0.3333333
-0.5	0	-0.5	-0.1666667	-0.2886751	-0.6666667
-0.5	0	0	-0.3333333	0	-0.3333333
-0.5	-0.5	0	-0.1666667	0.2886751	-0.6666667
0	-0.5	0	0.1666667	0.2886751	-0.3333333
0.5	0	0	0.3333333	0	0.3333333
0.5	0.5	0	0.1666667	-0.2886751	0.6666667
0	0.5	0	-0.1666667	-0.2886751	0.3333333
0	0.5	0.5	-0.3333333	0	0.6666667
0	0	0.5	-0.1666667	0.2886751	0.3333333
0	-0.5	0	0.1666667	0.2886751	-0.3333333
0.5	0.5	0.5	0	0	1
0	0	0	0	0	0
-0.5	-0.5	-0.5	0	0	-1

EXAMPLE

- USE A MULTILEVEL CONVERTER TO SYNTHESIZE A VECTOR $V_x = 0.4 V_{dc} \angle 25°$

$$V_x = (0.363 + j\,0.169)\, V_{dc}$$

FIND SOME VECTORS


0HL
LHL
HHL
0H0
L0L
HH0
00L
LH0
H0L
HHH
000
LLL
0HH
L00
H00
0LL
LHH
HLL
00H
LL0
H0H
0L0
L0H
HL0
LLH
0HL
HLH

$$V_1 = (0.333 + j\,0)\,V_{dc}$$

$$V_2 = (0.500 + j\,0.289)\,V_{dc}$$

$$V_3 = (0.167 + j\,0.289)\,(V_{dc})$$

$$\begin{bmatrix} Re(V_1) & Re(V_2) & Re(V_3) \\ Im(V_1) & Im(V_2) & Im(V_3) \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} = \begin{bmatrix} Re(V_d) \\ Im(V_d) \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} = \begin{bmatrix} 0.415 \\ 0.379 \\ 0.207 \end{bmatrix}$$

1	H	D	D	OLC
2	H	O	L	HOC
3	H	H	O	OOL

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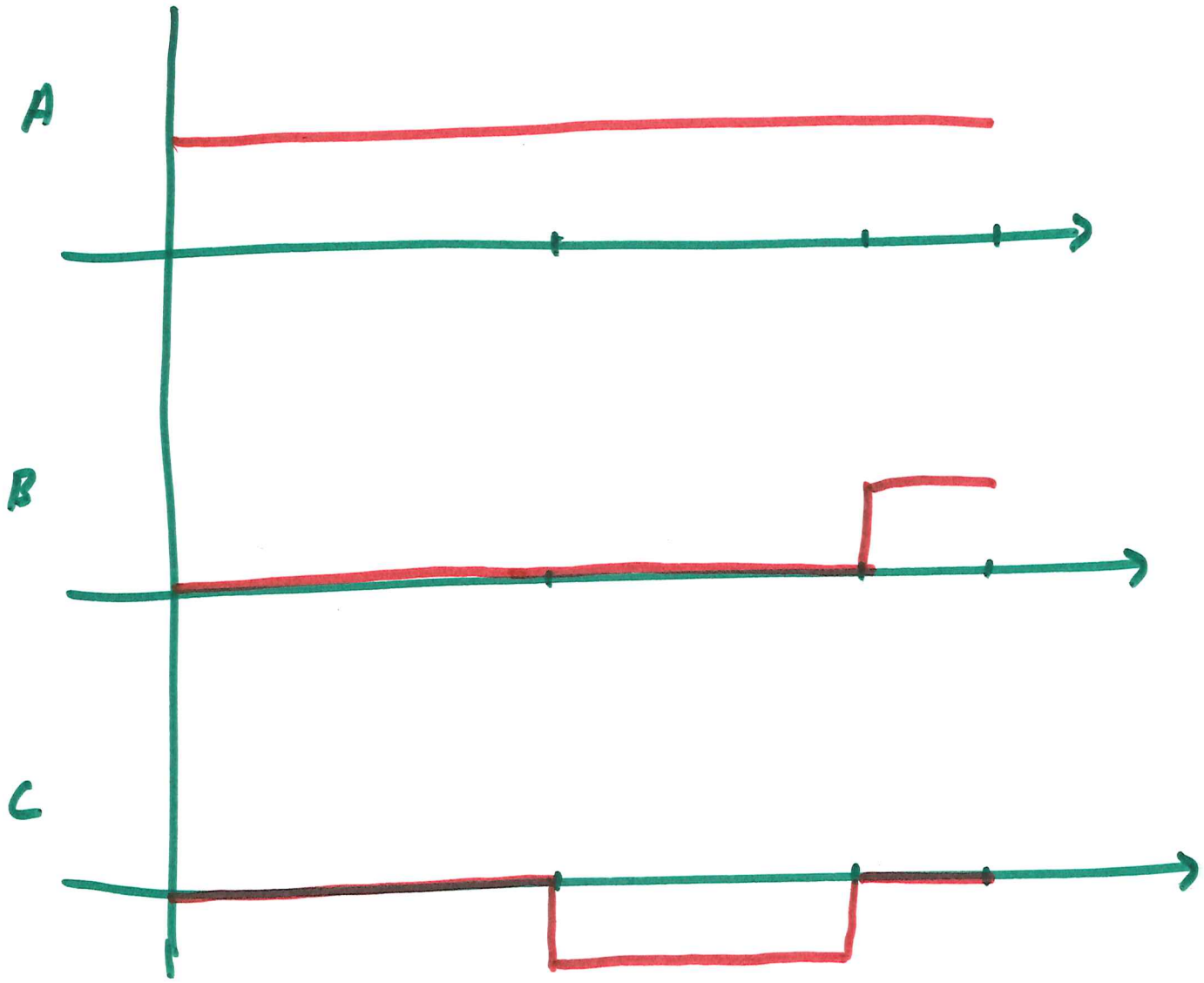

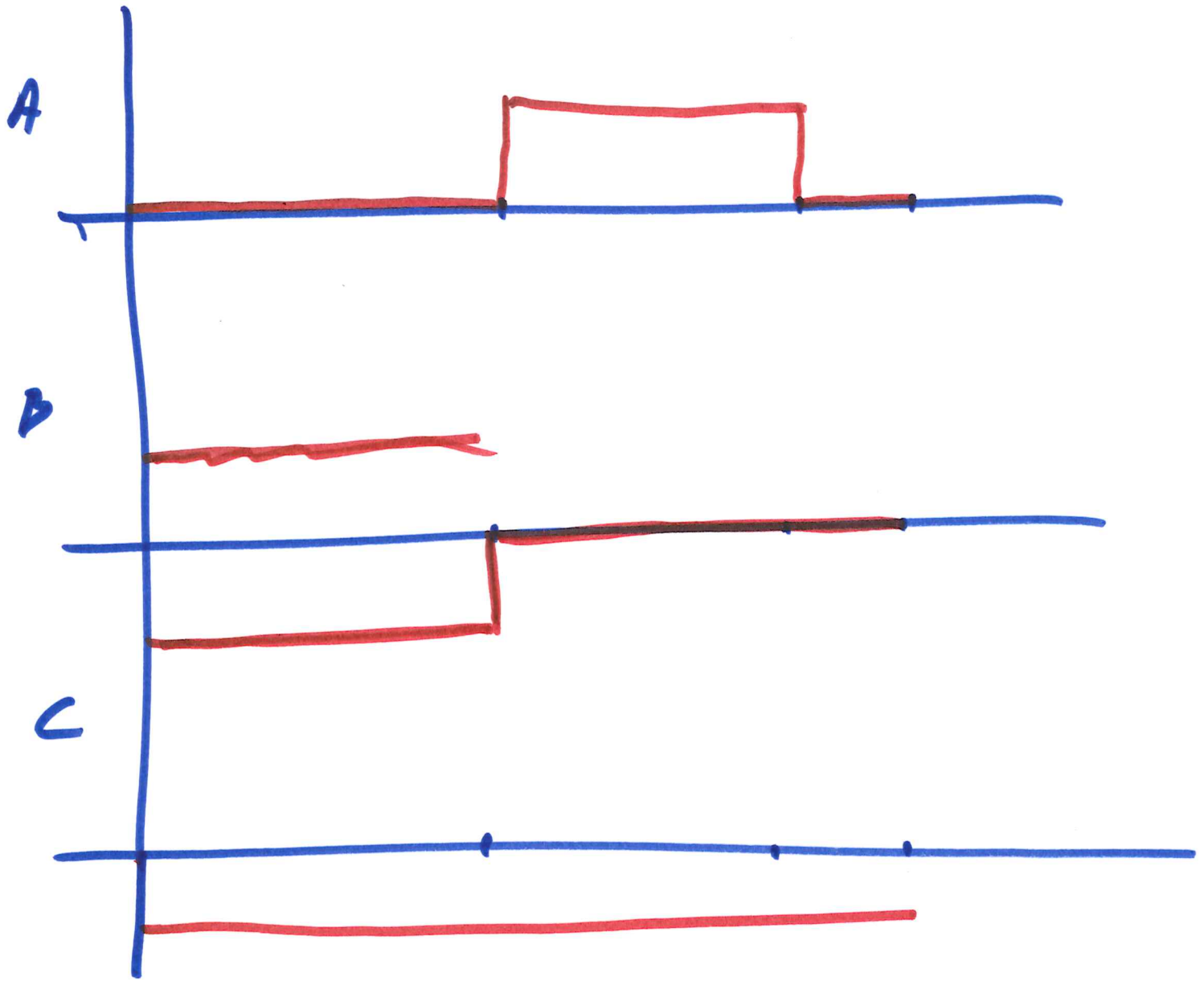
A
B
C

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T & D Applications of Voltage Sourced Converters

Lesson 16

Ref: Dynamics of Electrical Drives by Novotny and Lipo