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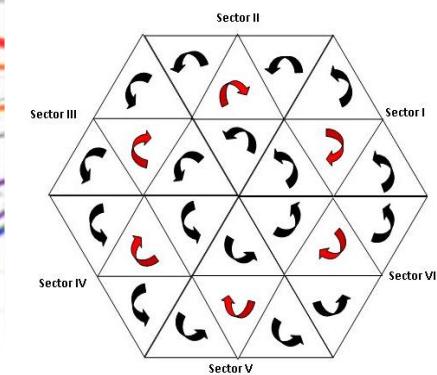
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Chapter 3

Permanent Magnet Synchronous Motor & Pulse Modulation

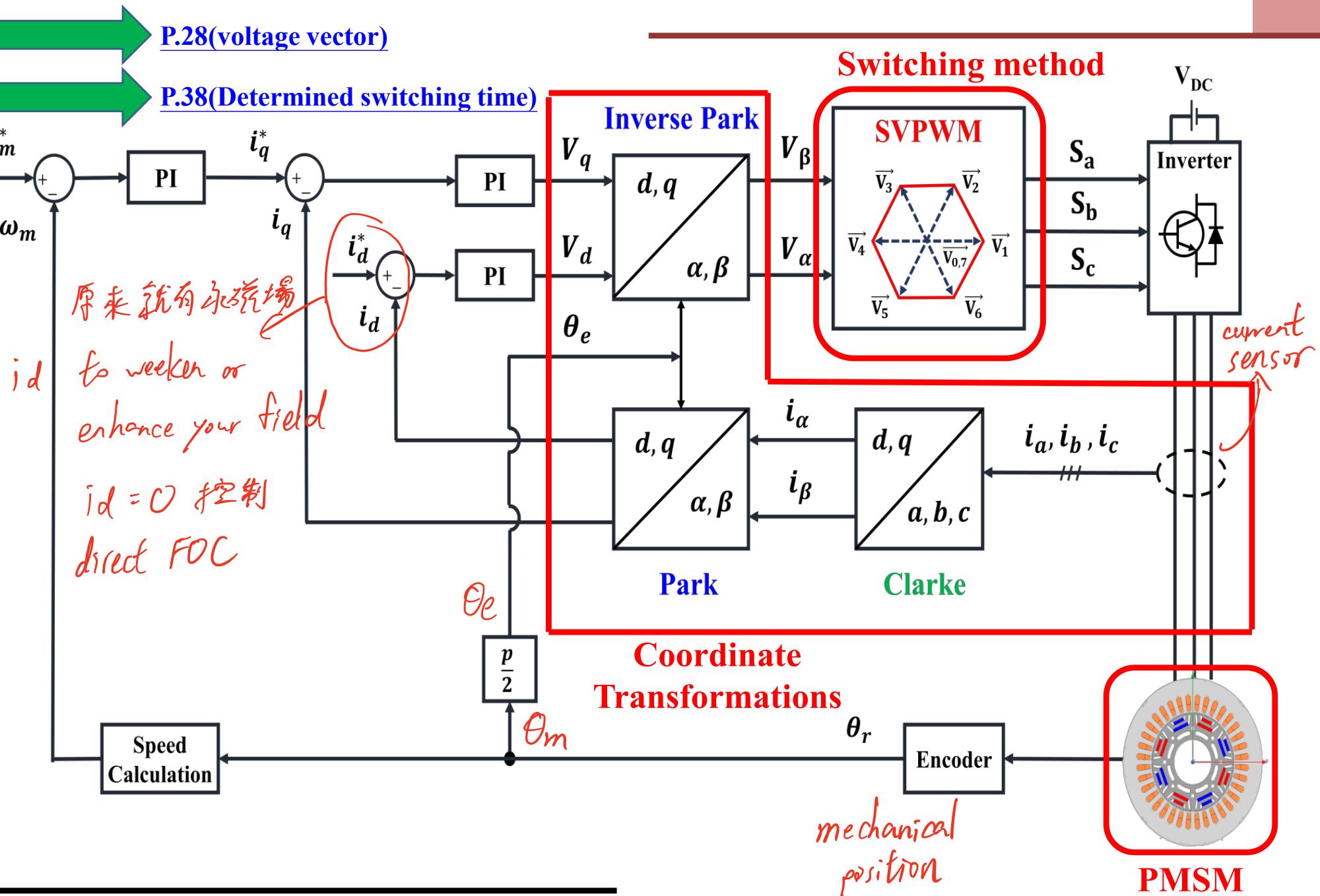
Professor Min-Fu Hsieh

Fall Semester - 2022



[https://www.researchgate.net/publication/318930471_SIMULATION
AND_IMPLEMENTATION_OF_TWO-LEVEL_AND_THREE-LEVEL_INVERTERS_BY_MATLAB_AND_RT-LAB/figures?lo=1](https://www.researchgate.net/publication/318930471_SIMULATION_AND_IMPLEMENTATION_OF_TWO-LEVEL_AND_THREE-LEVEL_INVERTERS_BY_MATLAB_AND_RT-LAB/figures?lo=1)

Control Architecture of FOC for PMSM





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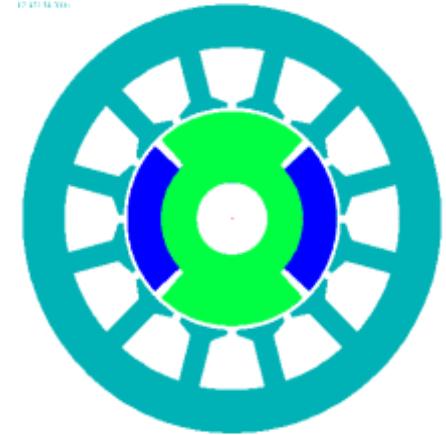
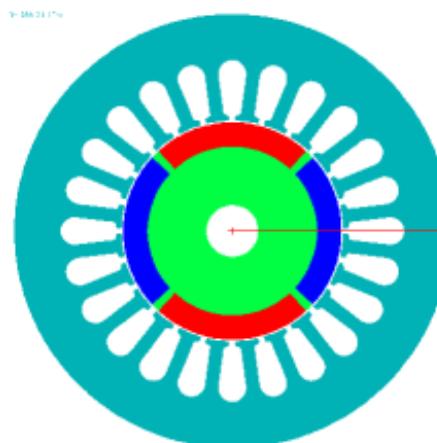
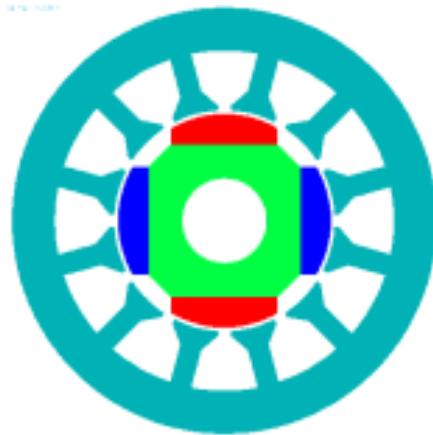
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Permanent Magnet Synchronous Motor (PMSM)

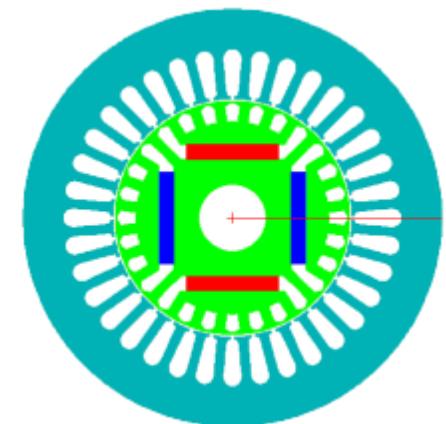
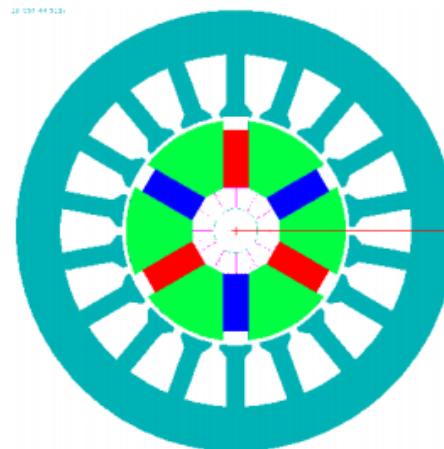
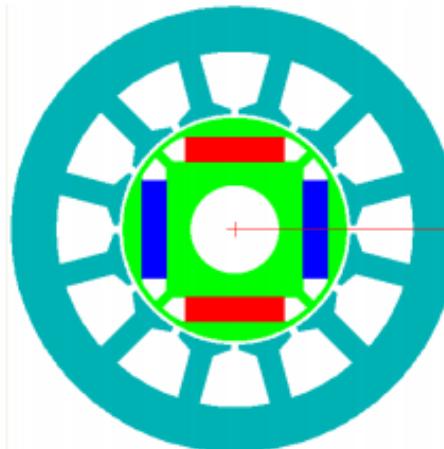
Types of PMSM

Base on configuration of permanent magnet in the rotor classified as:

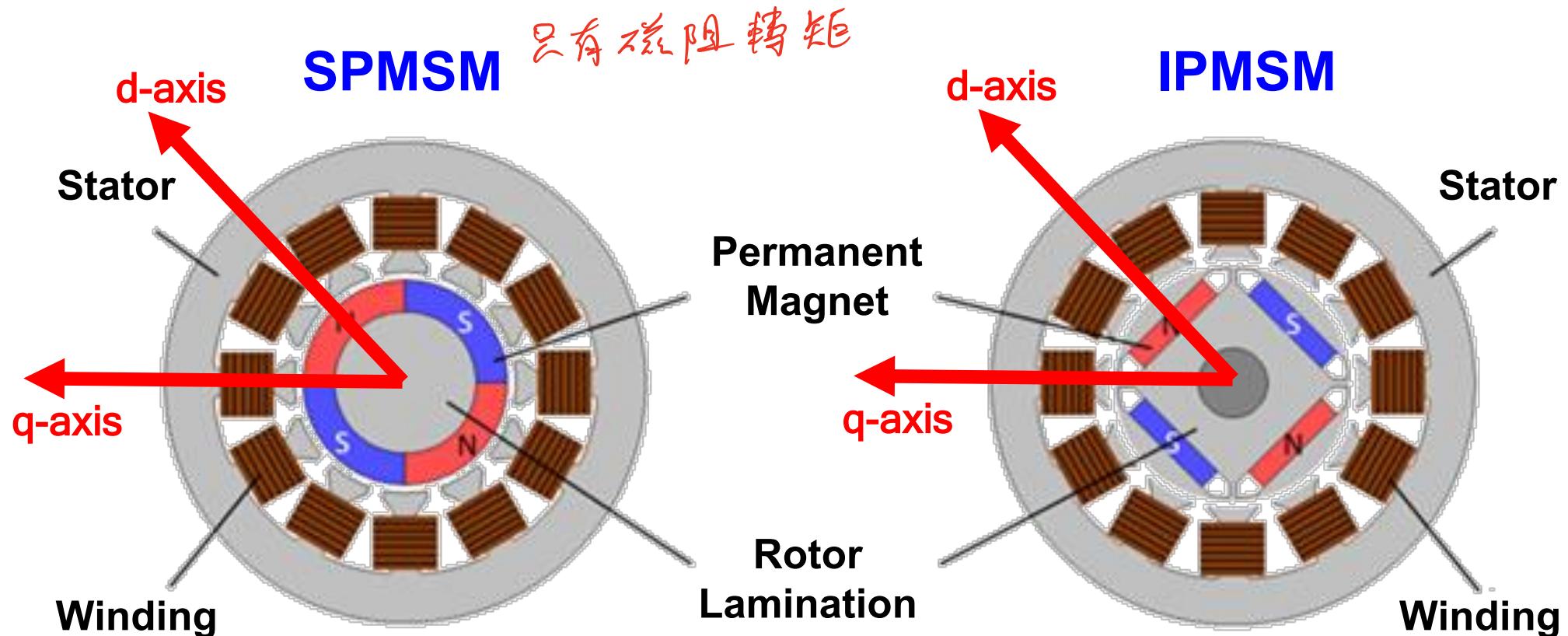
Surface Mounted
PMSM (SPMSM)



Interior
PMSM (IPMSM)



Comparison of PMSMs



Non – Salient: $L_d = L_q$



空

$$\text{成} \sim L = \frac{\lambda}{i} \rightarrow \text{磁交链}$$



Salient: $L_d < L_q$



L_q

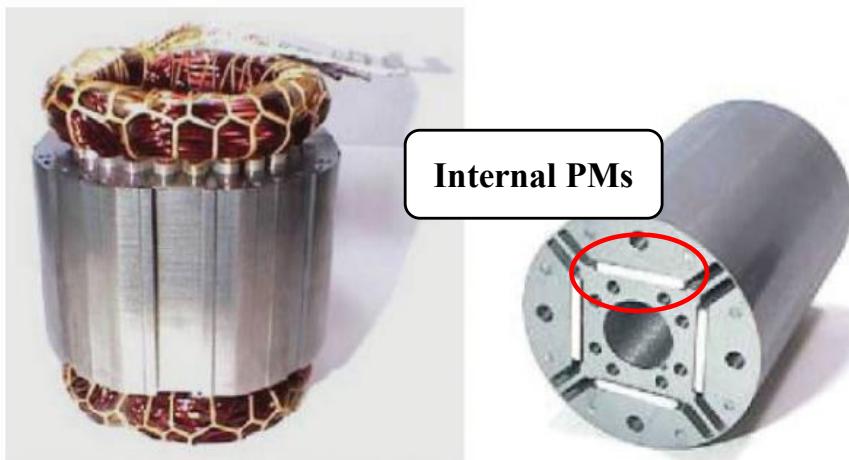
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L_d

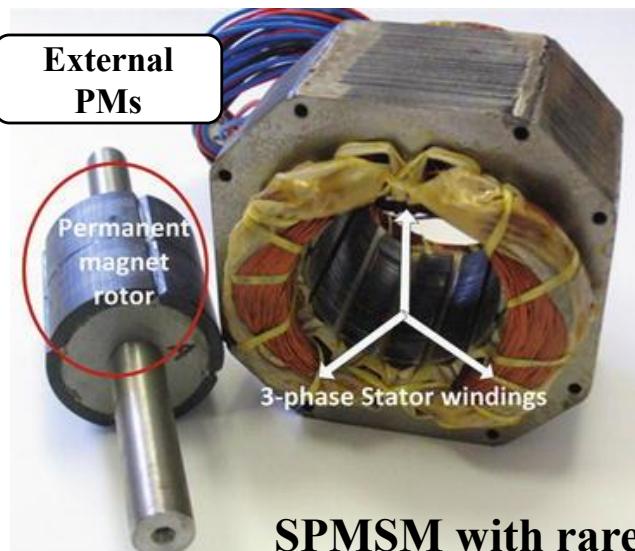
$\phi_q > \phi_d$
 $\lambda_q > \lambda_d$
 $L_q > L_d$

Index :
 L_d : d-axis inductance
 L_q : q-axis inductance

Comparison of PMSMs

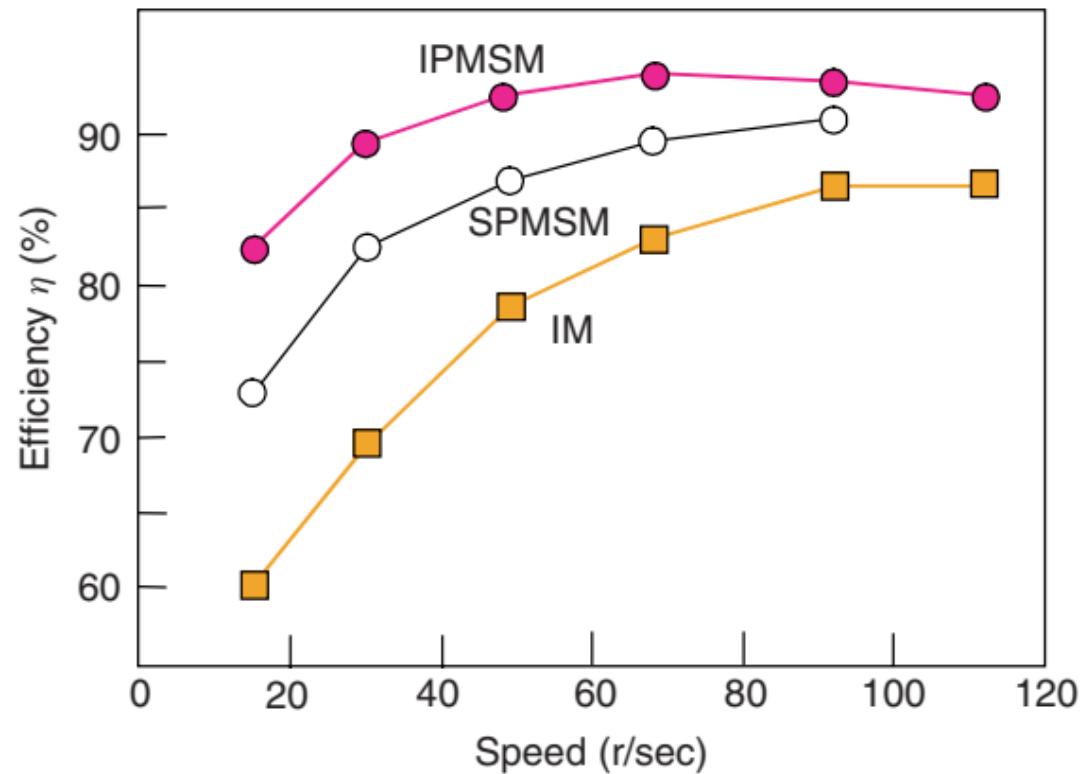


IPMSM with rare-earth PM
(Courtesy of Daikin Industries, Ltd)



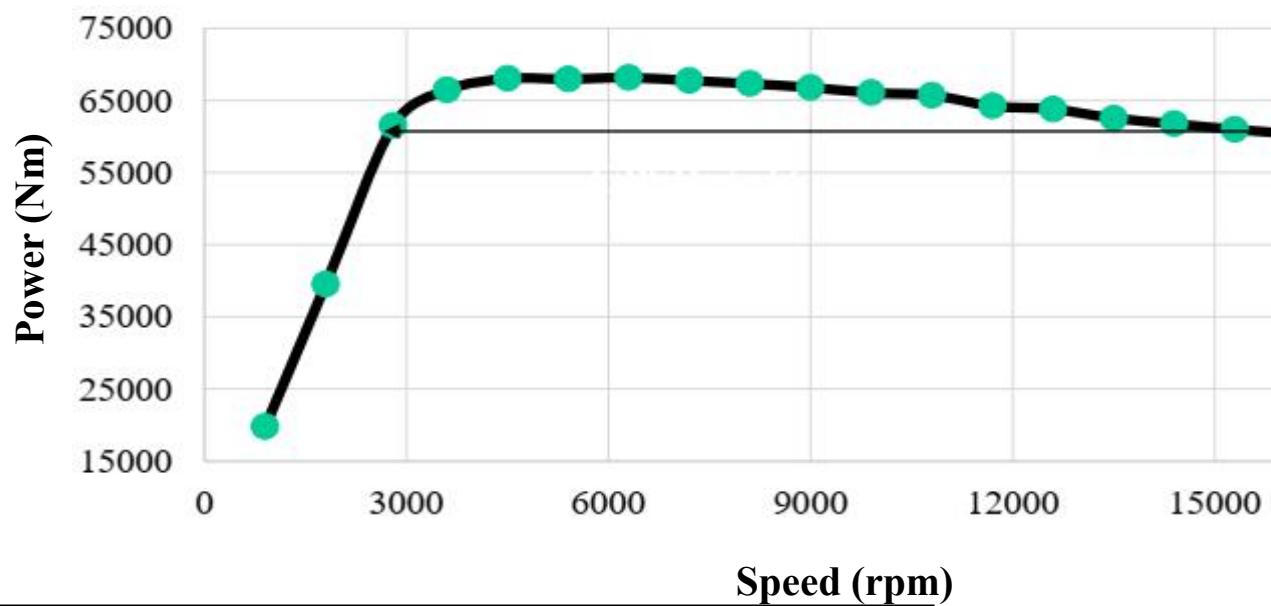
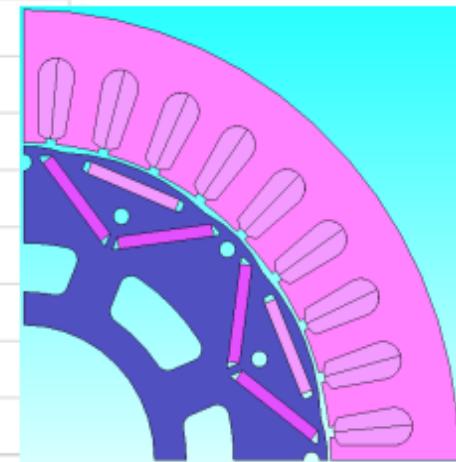
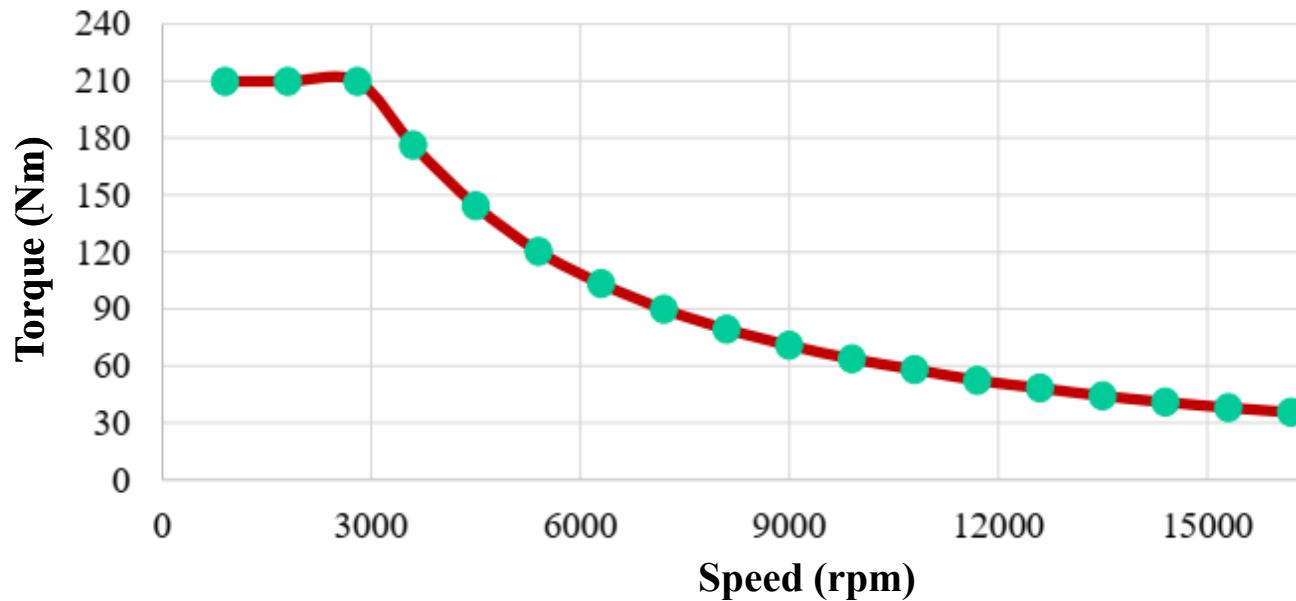
SPMSM with rare-earth PM.
(Courtesy of Daikin Industries, Ltd)

Comparative efficiency performances of IM, SPMSM and IPMSM (torque: 1.5 Nm).



Source: Shigeo Morimoto^{*a}, “Trend of Permanent Magnet Synchronous Machines”, IEEE Transactions On Electrical And Electronic Engineering, 2007

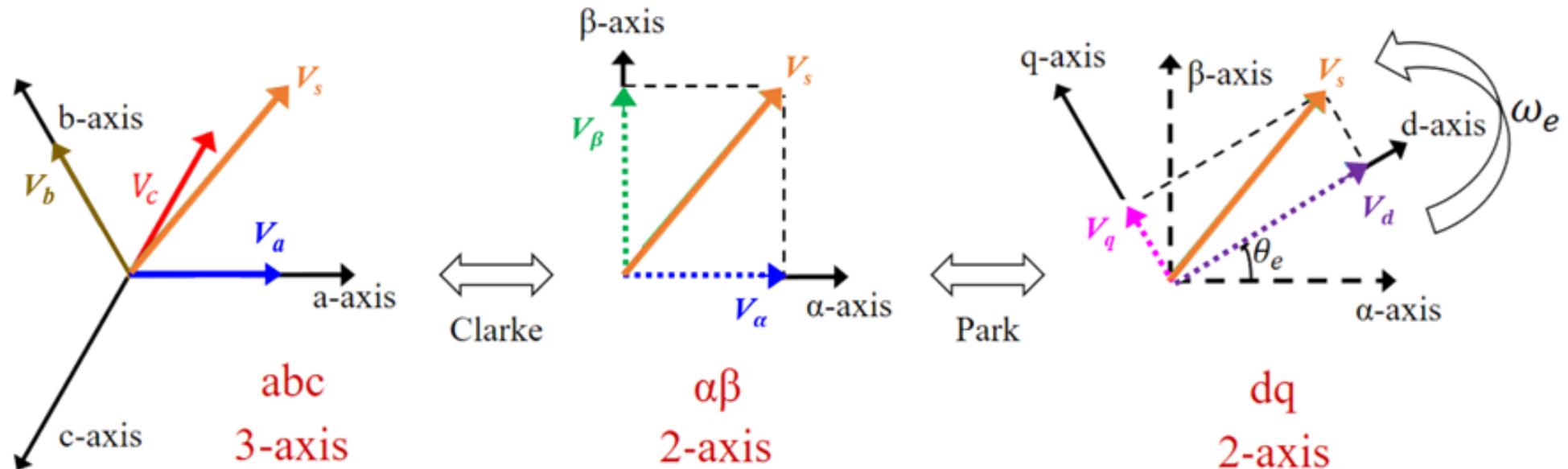
NCKU EMDSL 60kW IPM Motor



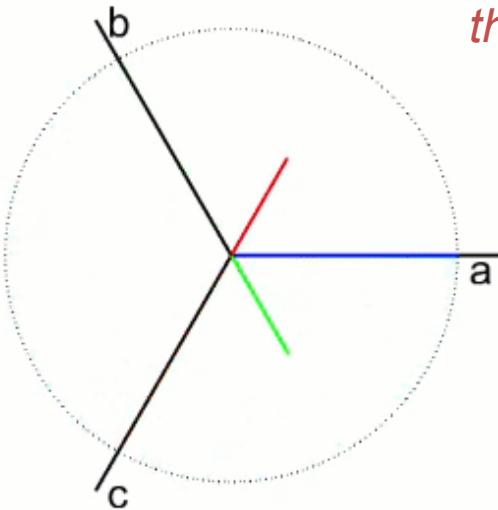
Coordinate Transformations

FOC：控制 AC 馬達
像控制 DC 馬達

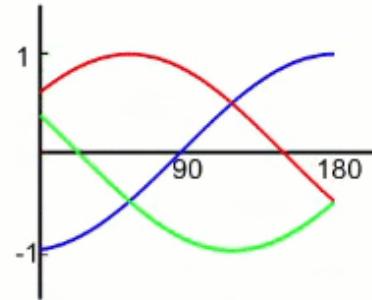
- The general simplified motor mathematical model will use a **Clarke Transformation** into the **two-axis stationary coordinate system** and then **Park Transformation** into the **two-axis rotating coordinate system** at an angular velocity ω_e
- In this way, the electrical and physical quantities in the rotating coordinate system can be regarded as the **DC physical quantity**, which simplifies the mathematical calculation



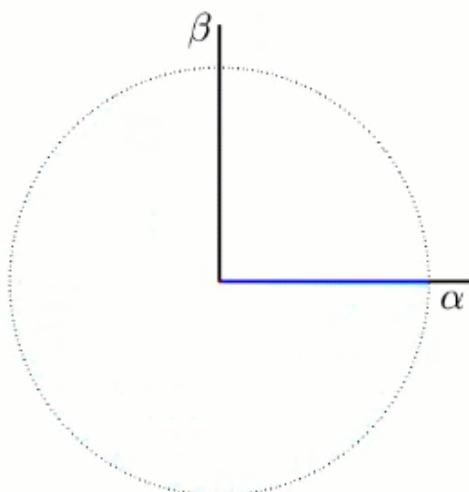
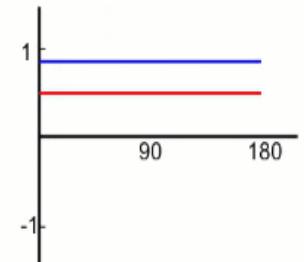
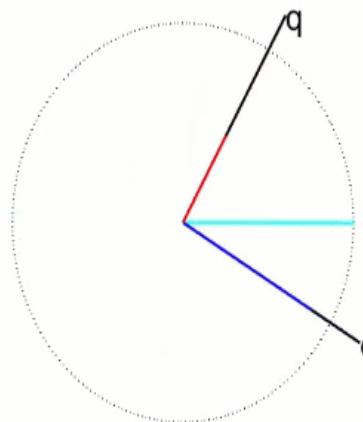
Coordinate Transformations



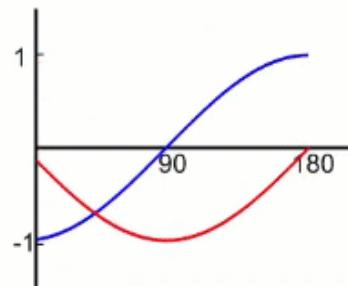
The time domain components of a three-phase system (in abc frame).



Resulting signals for the Park transform (dq).



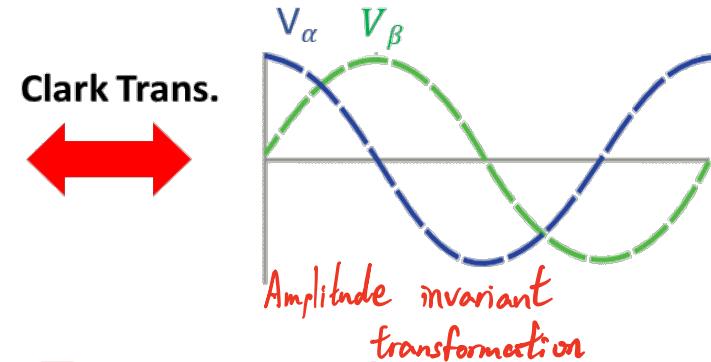
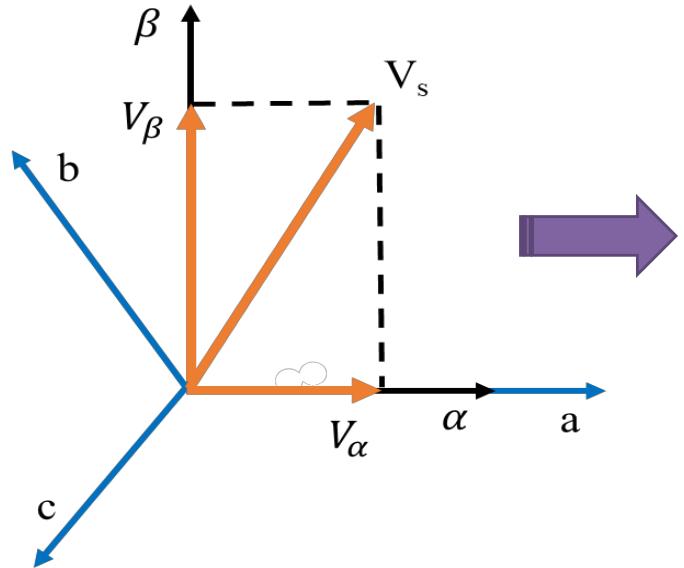
Resulting signals for the Clarke transform (αβ).



$$\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \end{bmatrix}$$

Clarke Transformation

等幅值 $\frac{2}{3} \left[\frac{1}{2} \frac{1}{2} - \frac{1}{2} \right] [V_c]$
等功率 $\sqrt{\frac{2}{3}}$



Voltage vector of V_s can be expressed as

$$\vec{V}_s = \vec{V}_\alpha + \vec{V}_\beta = \frac{2}{3} (\vec{V}_a + \vec{V}_b + \vec{V}_c)$$

Projected \vec{V}_s on the α - β axis, yields

$$\begin{cases} V_\alpha = \frac{2}{3} (\vec{V}_a \cdot \vec{\alpha} + \vec{V}_b \cdot \vec{\alpha} + \vec{V}_c \cdot \vec{\alpha}) \\ V_\beta = \frac{2}{3} (\vec{V}_a \cdot \vec{\beta} + \vec{V}_b \cdot \vec{\beta} + \vec{V}_c \cdot \vec{\beta}) \end{cases}$$

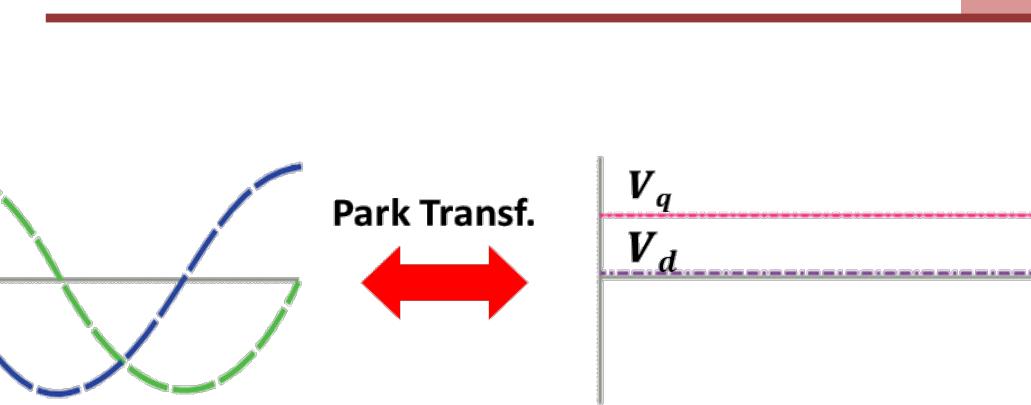
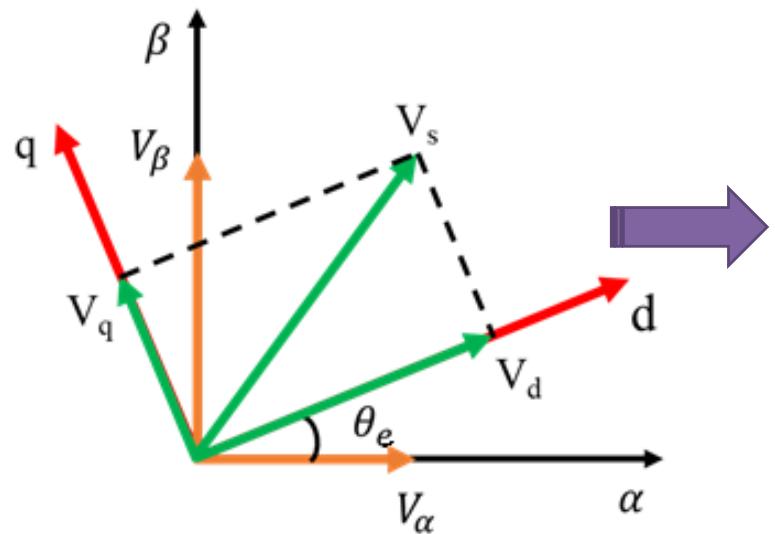
where $\vec{\alpha}, \vec{\beta}$ is the unit vector of the α - β axis

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_0 \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

Inverse Clarke Trans. equation

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & 1 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & 1 \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \\ V_0 \end{bmatrix}$$

Park Transformation



Similarly, projected \vec{V}_s on the α - β axis, yields

$$\begin{cases} V_d = \vec{V}_s \cdot \vec{d} = V_\alpha \cos(\theta_e) + V_\beta \sin(\theta_e) \\ V_q = \vec{V}_s \cdot \vec{q} = -V_\alpha \sin(\theta_e) + V_\beta \cos(\theta_e) \end{cases}$$

where \vec{d}, \vec{q} is the unit vector of the α - β axis

Park Trans. equation

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} \cos(\theta_e) & \sin(\theta_e) \\ -\sin(\theta_e) & \cos(\theta_e) \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix}$$

Inverse Park Trans. equation

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \begin{bmatrix} \cos(\theta_e) & -\sin(\theta_e) \\ \sin(\theta_e) & \cos(\theta_e) \end{bmatrix} \begin{bmatrix} V_d \\ V_q \end{bmatrix}$$



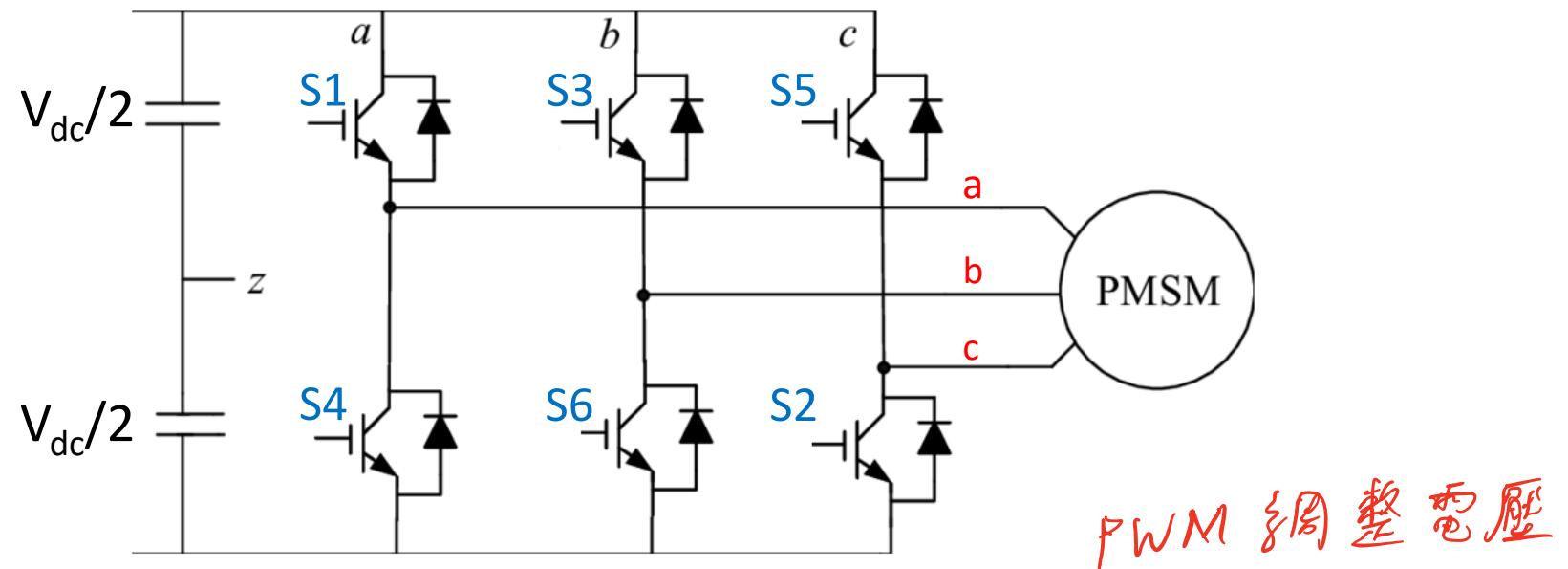
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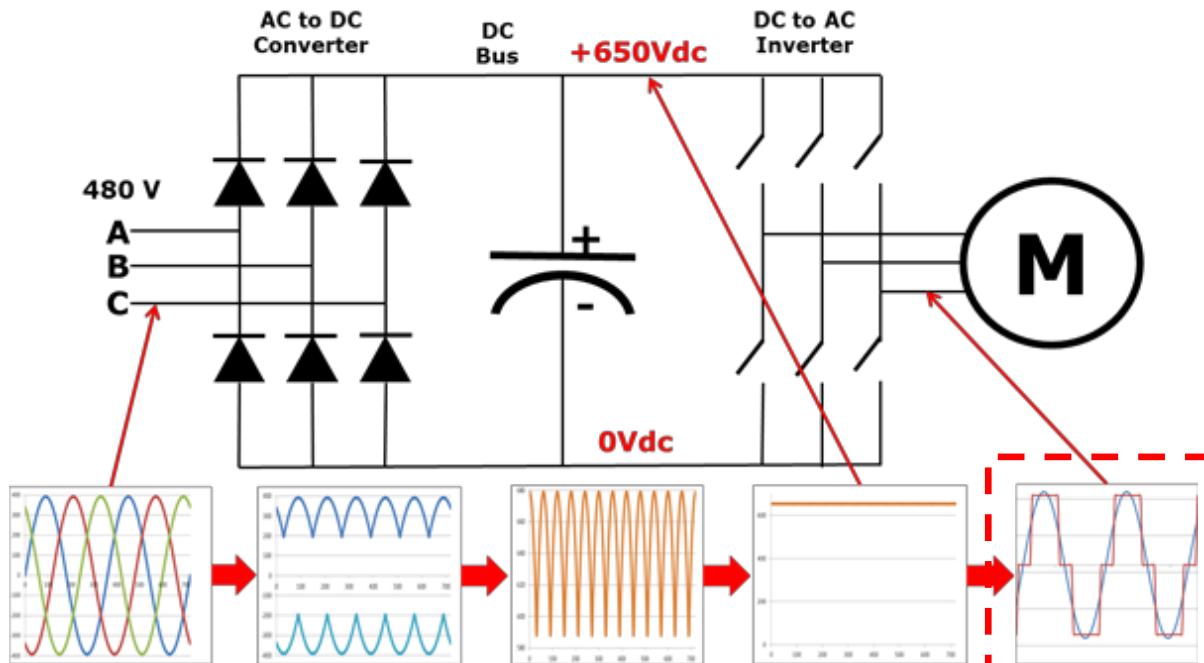
Pulse Width Modulation (PWM)

Three Phase Inverter Control

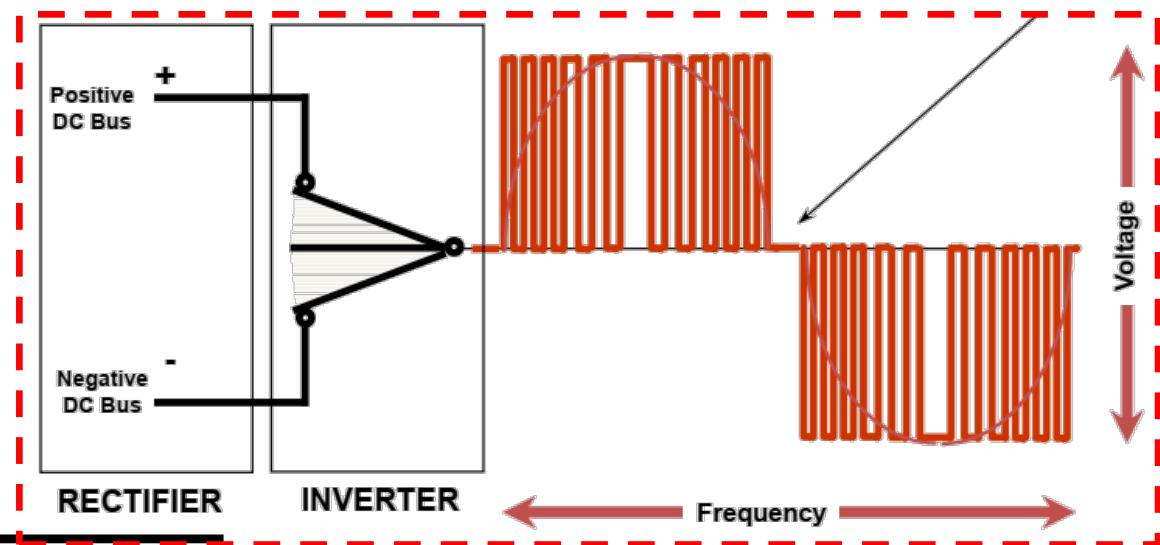
An inverter fed 3-phase AC motor with three phase windings a, b and c. The three phase voltages are applied by three pairs of semiconductor switches (S1 through S6) with amplitude, frequency and phase angle defined by microcontroller calculated pulse patterns. The inverter is fed by the DC link voltage V_{dc}



PWM in a AC Drive



How often you switch from positive pulses to negative pulses determines the frequency of the waveform



Pulse-Width Modulation (PWM)

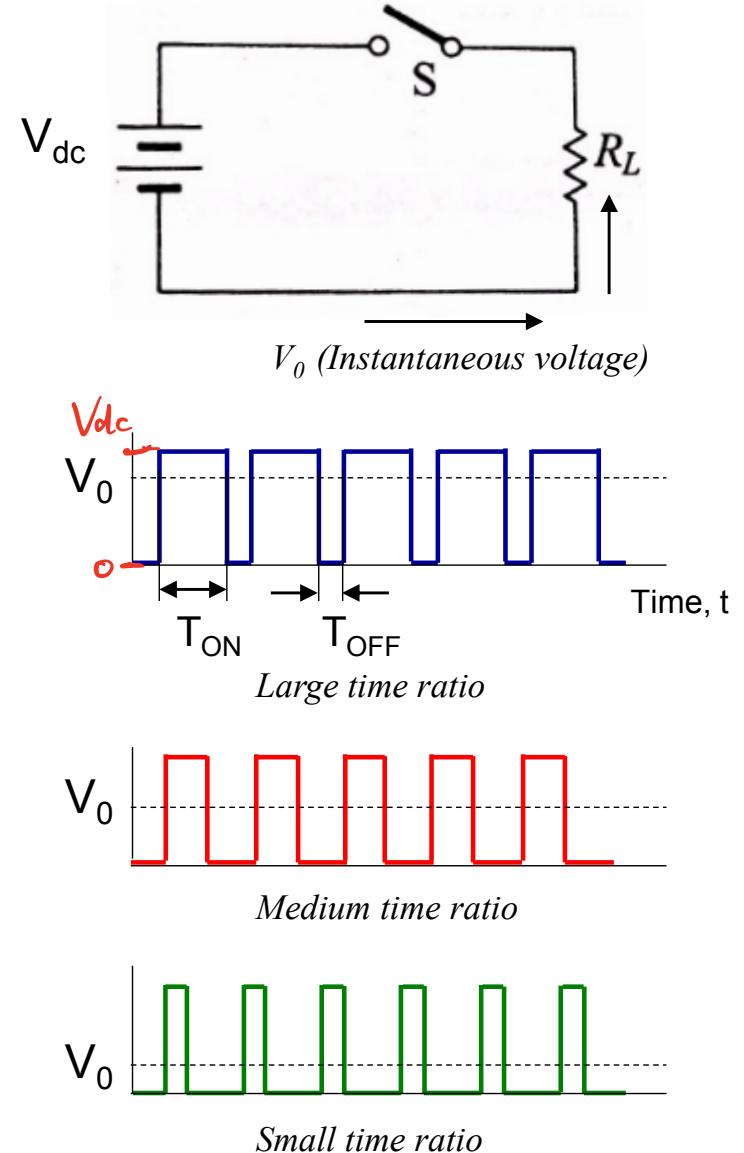
The basic principle of PWM can be stated that under constant supply voltage V_{dc} , when voltage is applied to the resistance load in pulses. The instantaneous output voltage v_0 is determined:

$$V_0 = \frac{T_{ON}}{T_{ON} + T_{OFF}} V_{dc}$$

The voltage applied to the load can thus be changed using the time duty-cycle ratio

$$m = \frac{T_{ON}}{T_{ON} + T_{OFF}}$$

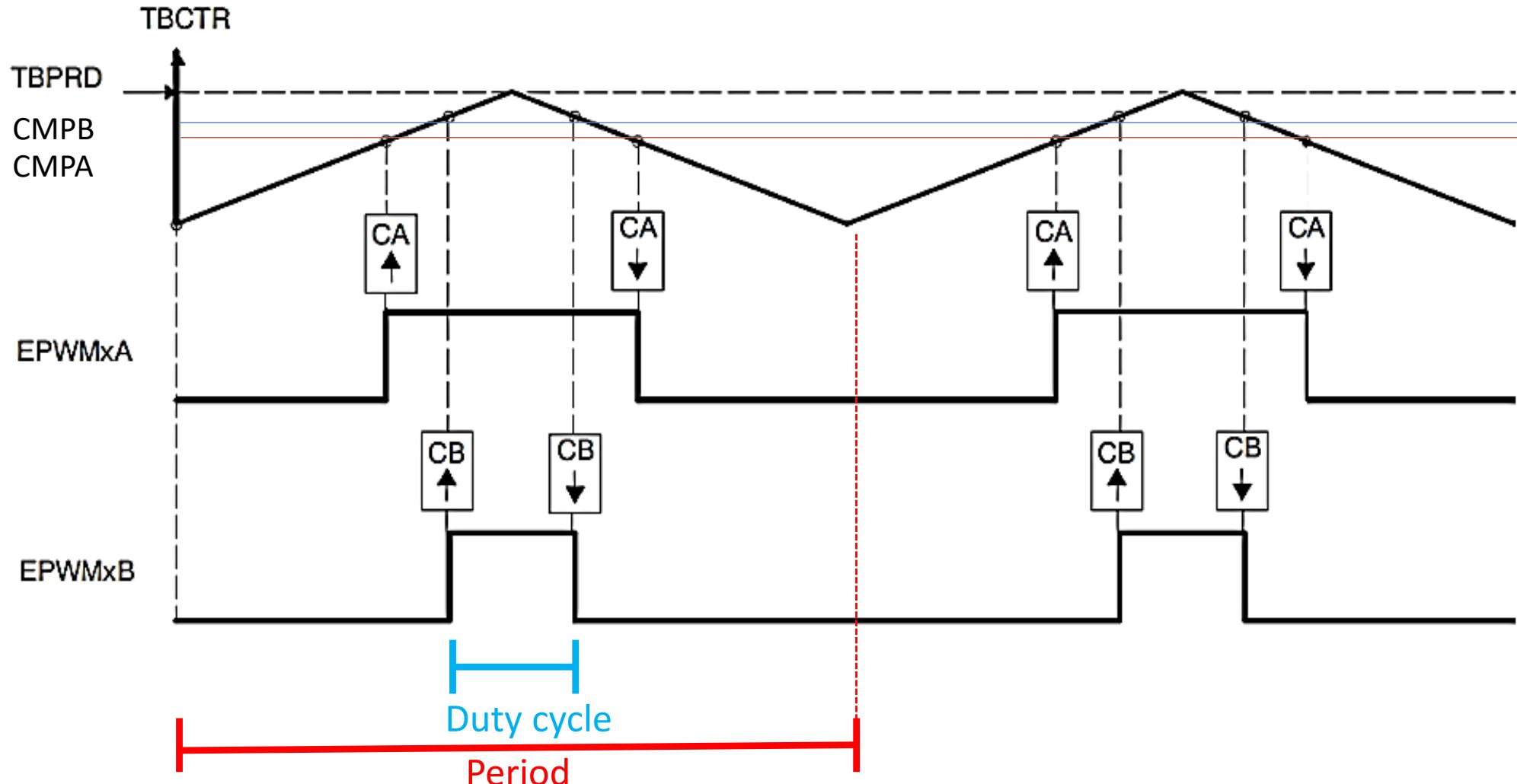
Pulses with fixed frequency and magnitude but variable width



Pulse-Width Modulation (PWM)

- PWM generated by DSP (Example)

比較器





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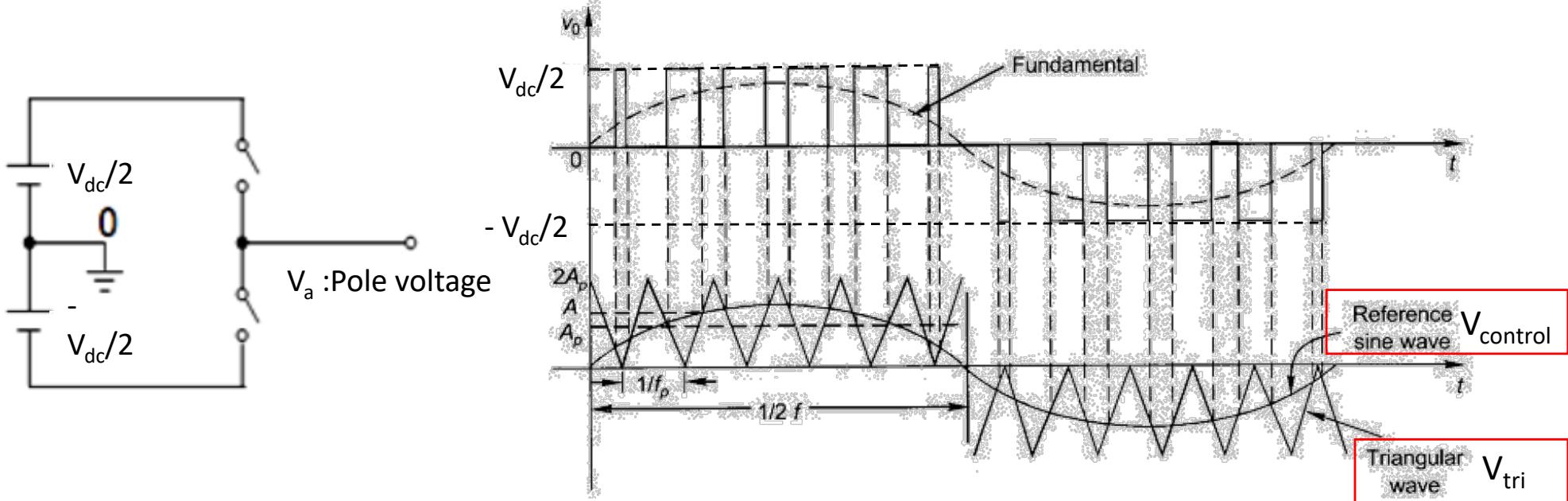
Sinusoidal Pulse Width Modulation (SPWM)

- With advances in solid-state power electronic devices and microprocessors, various inverter control techniques employing pulse width modulation (PWM) techniques are becoming increasingly popular in AC motor drive application, especially with PMSM. These PWM-based drives are used to **control both the frequency and the magnitude of the voltage applied to motors.**
- In this chapter, **Sinusoidal PWM (SPWM)** and **Space vector PWM (SVPWM)** will be introduced and compared about definition, principle, harmonic and efficiency...

Sinusoidal Pulse Width Modulation (SPWM)

Sinusoidal PWM is a type of "carrier-based" pulse width modulation, carrier based PWM uses pre-defined modulation signals to determine output voltages.

SPWM schemes generate the switching position patterns by comparing *reference sine wave* signal with a *carrier triangular wave* signal.



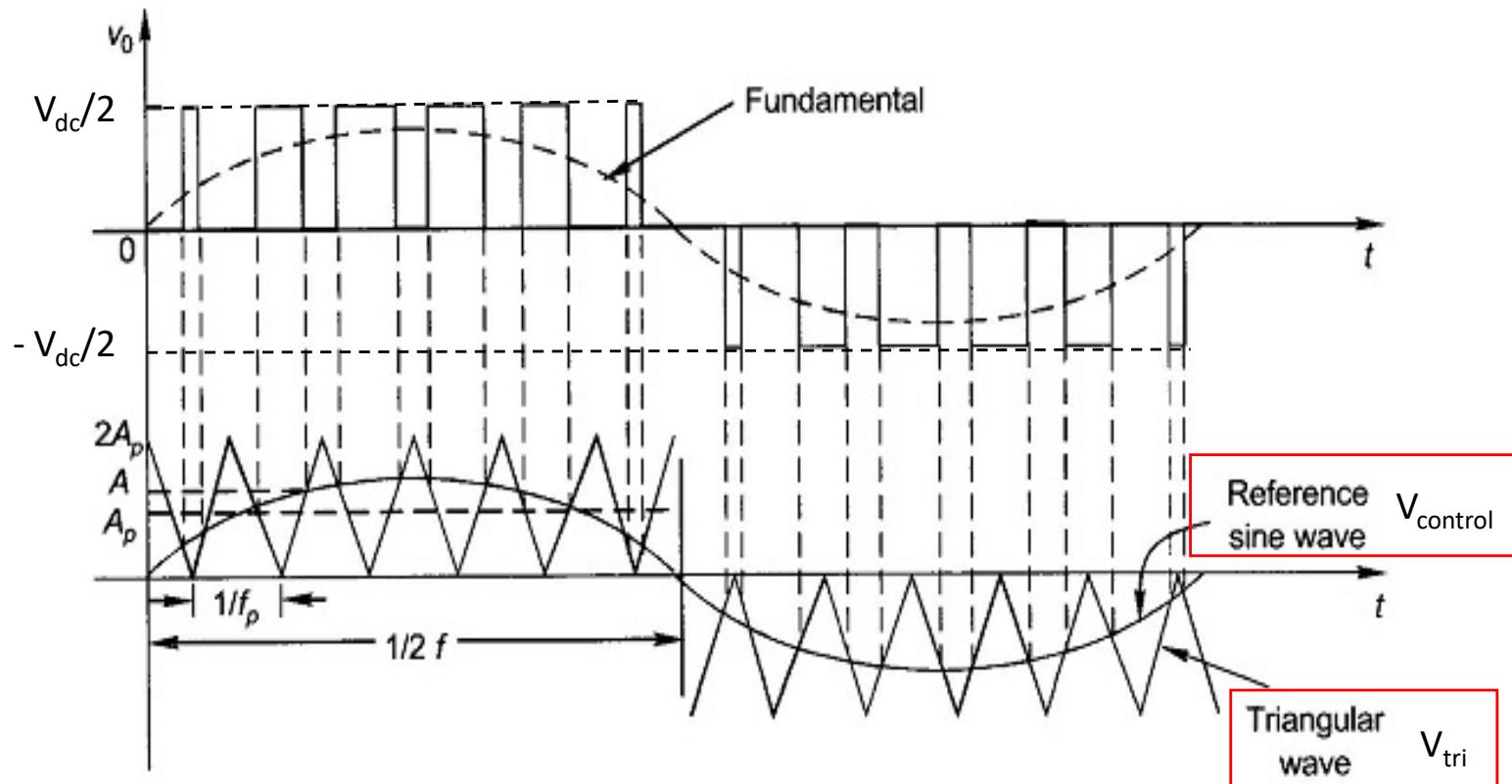
***Considering the circuit model of a single-phase inverter with a centre-tapped grounded DC bus illustrate principle of pulse width modulation.

Principle of SPWM

The inverter output voltage is determined in the following

When $V_{\text{control}} > V_{\text{tri}}$, $V_{\text{ao}} = V_{\text{dc}}/2$

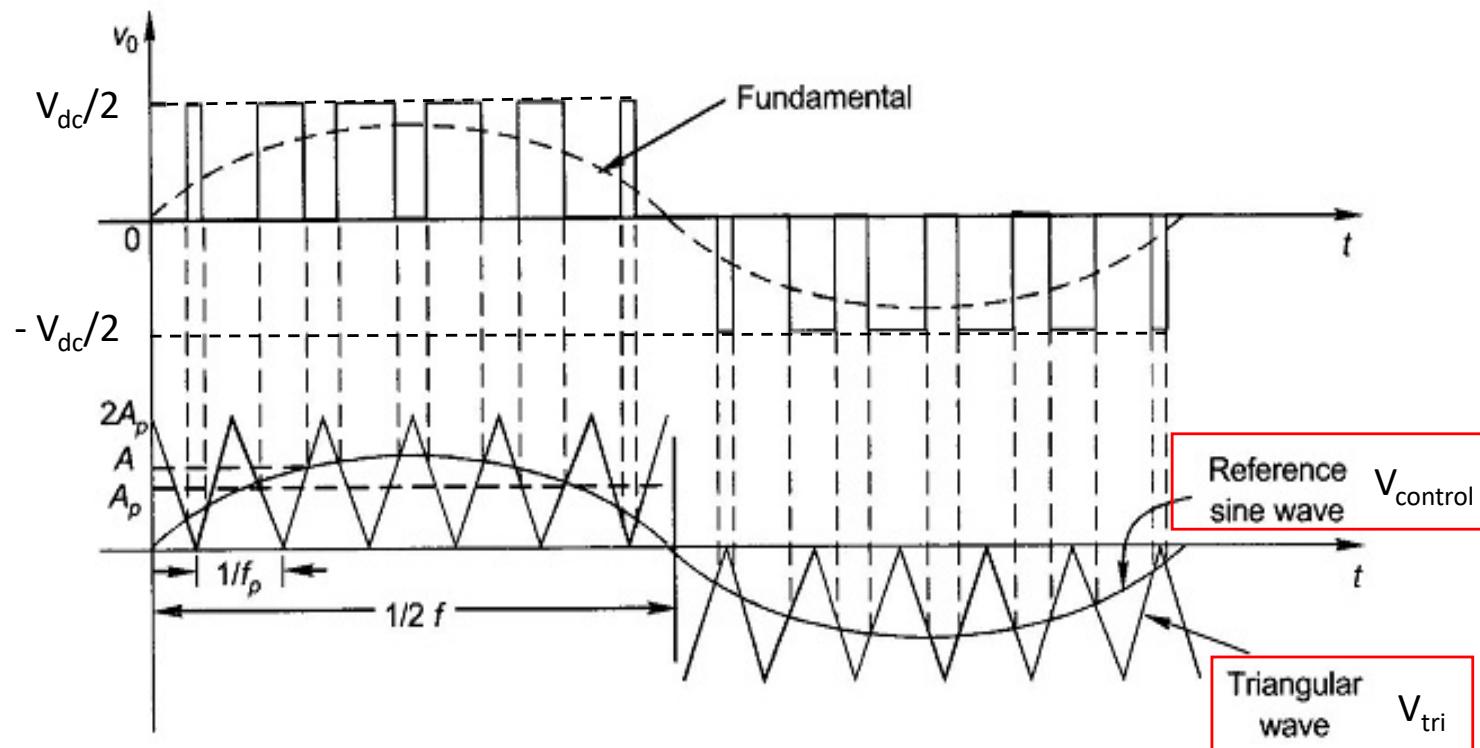
When $V_{\text{control}} < V_{\text{tri}}$, $V_{\text{ao}} = -V_{\text{dc}}/2$



Principle of SPWM

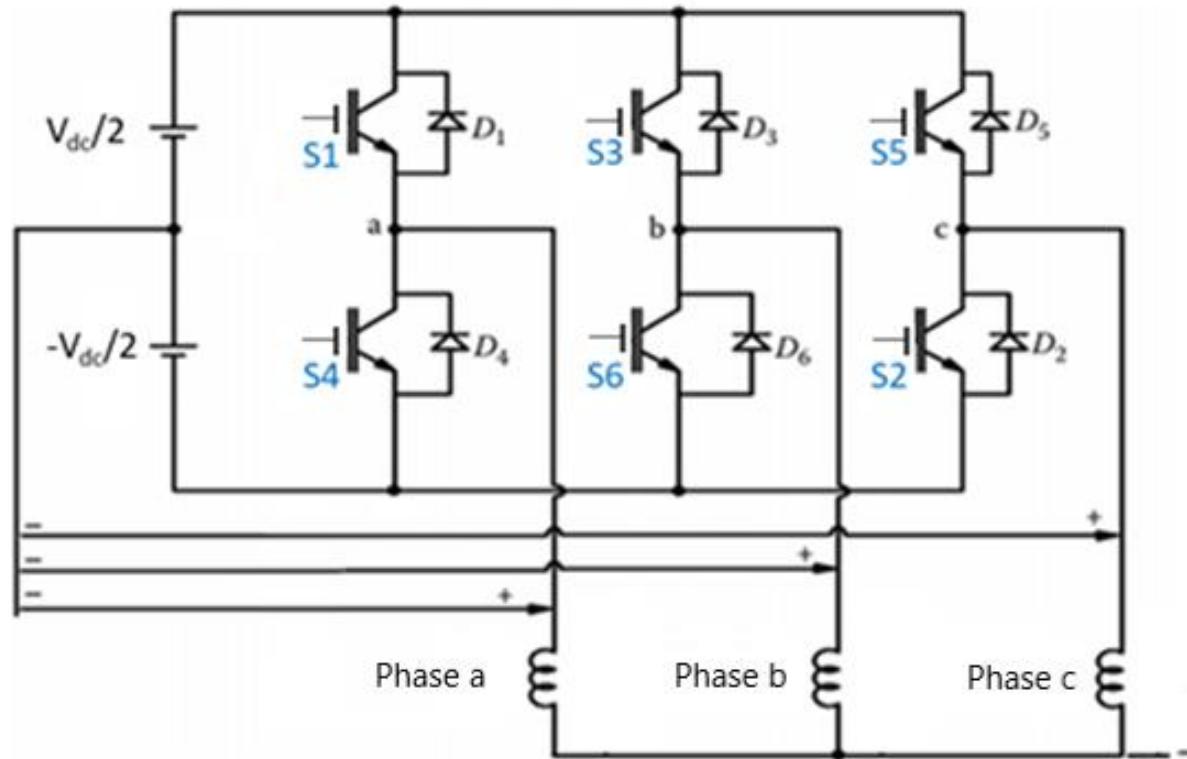
The inverter output voltage has the following features:

- PWM frequency is the same as the frequency of V_{tri}
- Amplitude is controlled by the peak value of V_{control}
- Fundamental frequency is controlled by the frequency of V_{control}



Principle of SPWM

Considering circuit model of three-phase PWM inverter shows waveforms of carrier wave signal (V_{tri}) and control signal ($V_{control}$), inverter output **line to neutral voltages are V_{a0}, V_{b0}, V_{c0} , inverter output line to line voltages are V_{ab}, V_{bc}, V_{ca}** respectively.



Principle of SPWM

Inverter output voltage

For Phase a:

If $V_{control} > V_{triangle}$ then $V_{ao} = V_{dc}/2$.

If $V_{control} < V_{triangle}$ then $V_{ao} = -V_{dc}/2$.

For Phase b:

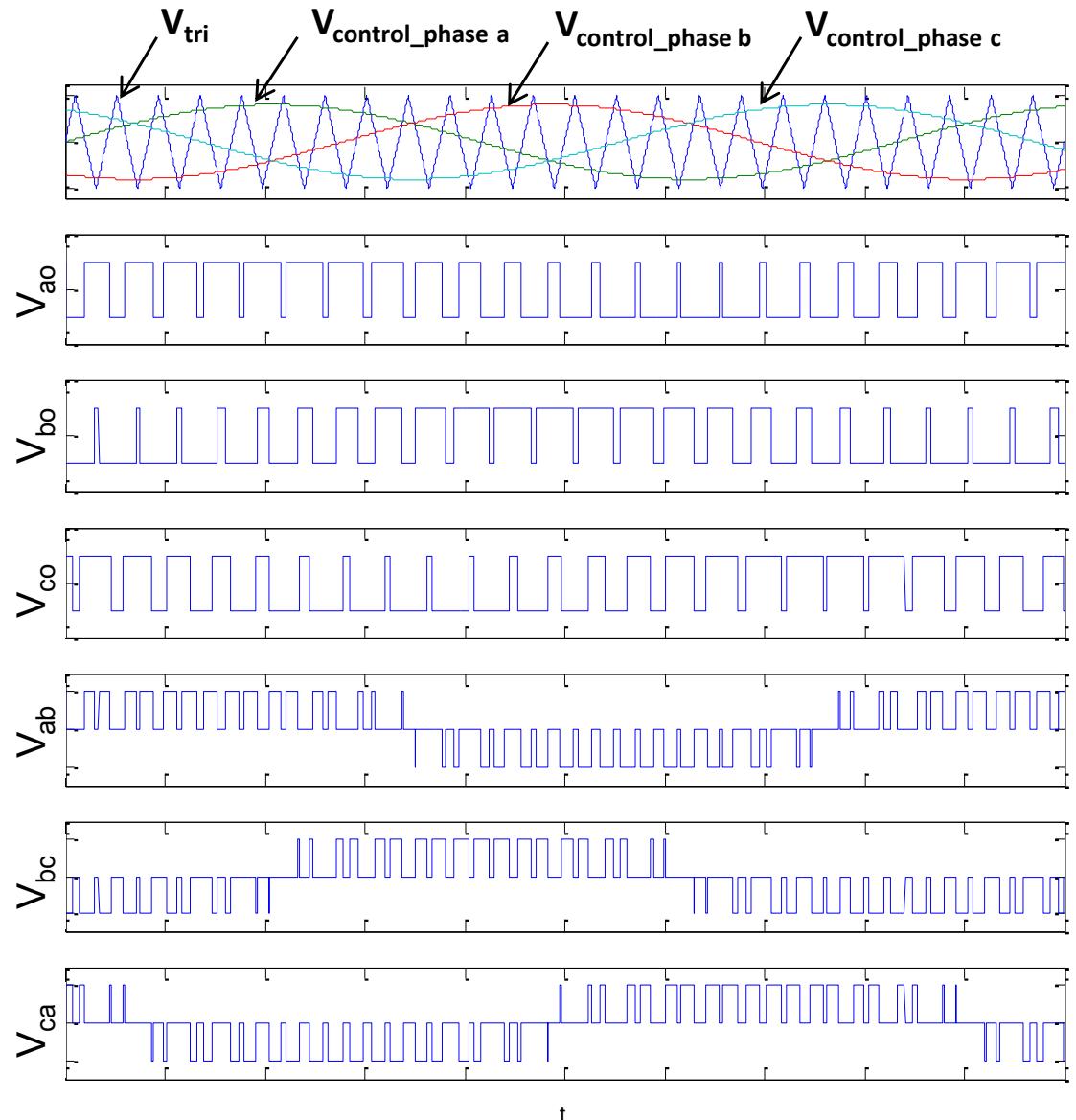
If $V_{control} > V_{triangle}$ then $V_{bo} = V_{dc}/2$.

If $V_{control} < V_{triangle}$ then $V_{bo} = -V_{dc}/2$.

For Phase c:

If $V_{control} > V_{triangle}$ then $V_{co} = V_{dc}/2$.

If $V_{control} < V_{triangle}$ then $V_{co} = -V_{dc}/2$.



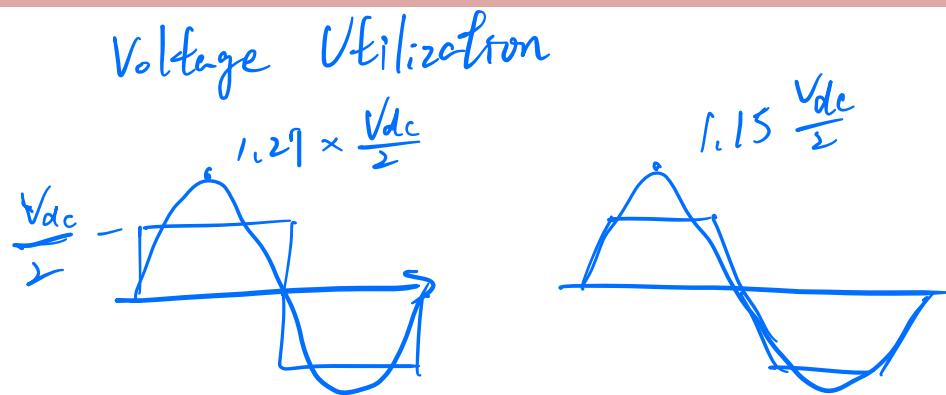


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Space Vector Pulse Width Modulation (SVPWM)

提高電壓利用率



The working principle of SVPWM is to synthesize the stator current to be generated by using the basic voltage vector of the three-phase PWM Inverter. This combined current generates a rotating stator flux vector on the stator coil and interacts with the rotor flux to generate torque, which causes the motor to rotate.

By controlling the voltage vector, the motor air gap rotating flux vector trajectory approaches an ideal circle with minimal flux chopping. Since the torque ripple is the lowest, the speed ripple is also minimized in the case of open circuit control.

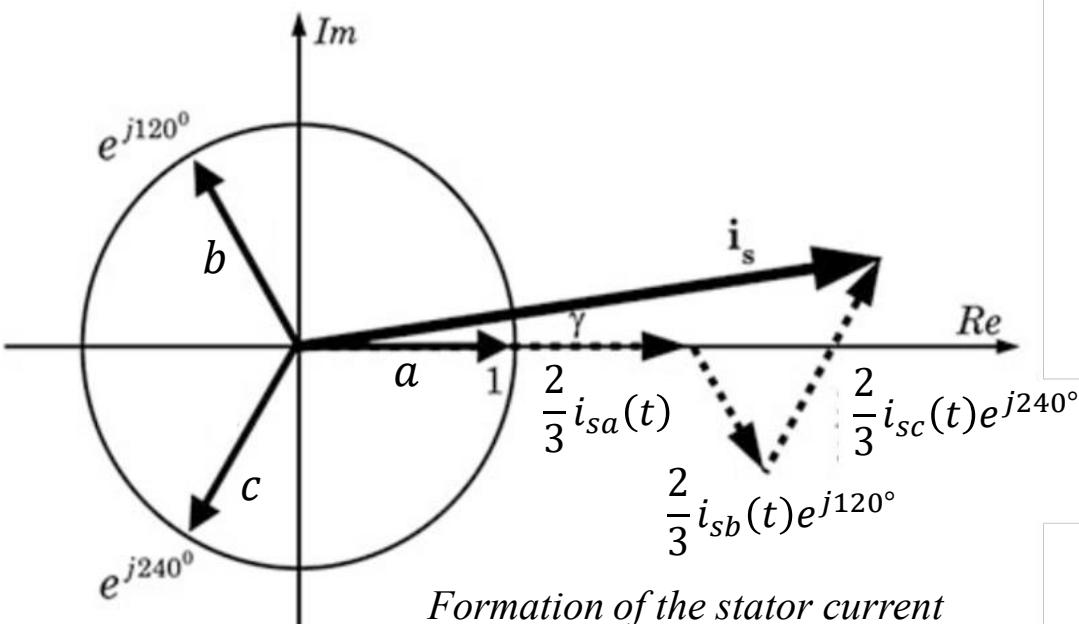
Formation of the Space Vectors

The three sinusoidal phase currents i_a , i_b and i_c of a neutral point isolated 3-phase AC machine fulfill the following relation:

$$i_a(t) + i_b(t) + i_c(t) = 0$$

These currents can be combined to a vector $i_s(t)$ circulating with the stator frequency f_s

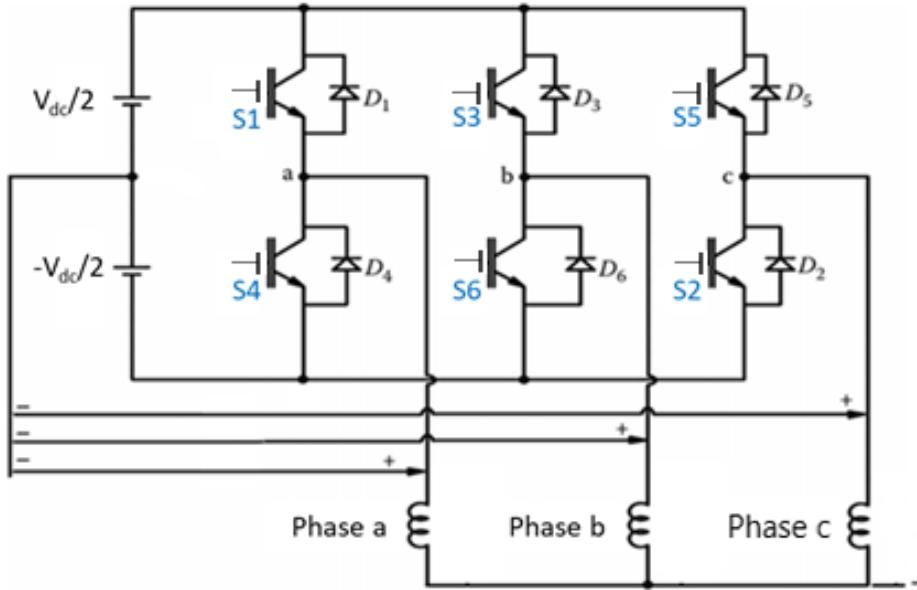
$$i_s = \frac{2}{3} [i_{sa}(t) + i_{sb}(t)e^{j\gamma} + i_{sc}(t)e^{j2\gamma}], \quad \text{with } \gamma = \frac{2\pi}{3} = 120^\circ$$



The three phase currents now represent the projections of the vector i_s on the accompanying winding axes. Using this idea to combine other 3-phase quantities, complex vectors of **stator and rotor voltages** v_s , v_r and **stator and rotor flux linkages** ψ_s , ψ_r are obtained. All vectors circulate with the angular **speed** ω_s .

Can also be voltage or flux vectors

Principle of SVPWM



- When an **upper switch** is turned on (i.e., a, b or c is “1”), the corresponding **lower switch** is turned off (i.e., a, b or c is “0”)
- Eight voltage vector ($\vec{V}_0, \vec{V}_1, \dots, \vec{V}_7$) is combinations of on and off patterns for the three upper transistors (S1, S3, S5)

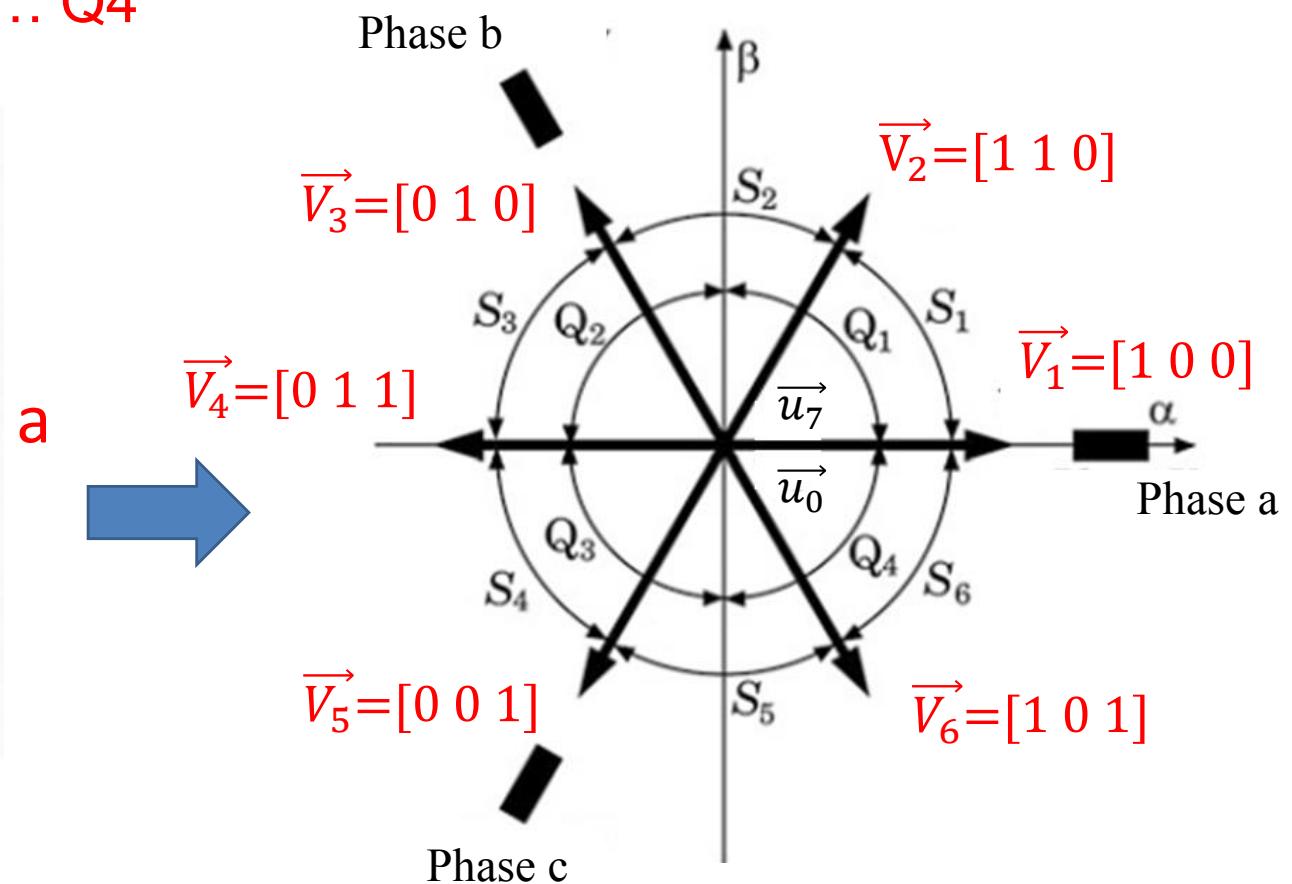
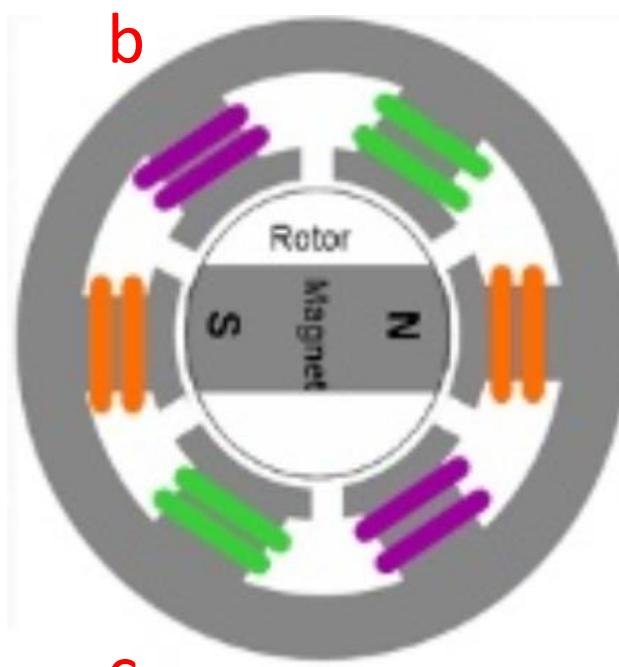
Table 5.1. All ON/OFF states of upper and lower switch in SVPWM

$\vec{V}_0 = [0\ 0\ 0]$	$\vec{V}_1 = [1\ 0\ 0]$	$\vec{V}_2 = [1\ 1\ 0]$	$\vec{V}_3 = [0\ 1\ 0]$	$\vec{V}_4 = [0\ 1\ 1]$	$\vec{V}_5 = [0\ 0\ 1]$	$\vec{V}_6 = [1\ 0\ 1]$	$\vec{V}_7 = [1\ 1\ 1]$
S1:OFF	S1:ON	S1:ON	S1:OFF	S1:OFF	S1:OFF	S1:ON	S1:ON
S3:OFF	S3:OFF	S3:ON	S3:ON	S3:ON	S3:OFF	S3:OFF	S3:ON
S5:OFF	S5:OFF	S5:OFF	S5:OFF	S5:ON	S5:ON	S5:ON	S5:ON
S4:ON	S4:OFF	S4:OFF	S4:ON	S4:ON	S4:ON	S4:OFF	S4:OFF
S6:ON	S6:ON	S6:OFF	S6:OFF	S6:OFF	S6:ON	S6:ON	S6:OFF
S2:ON	S2:ON	S2:ON	S2:ON	S2:OFF	S2:OFF	S2:OFF	S2:OFF

Principle of SVPWM

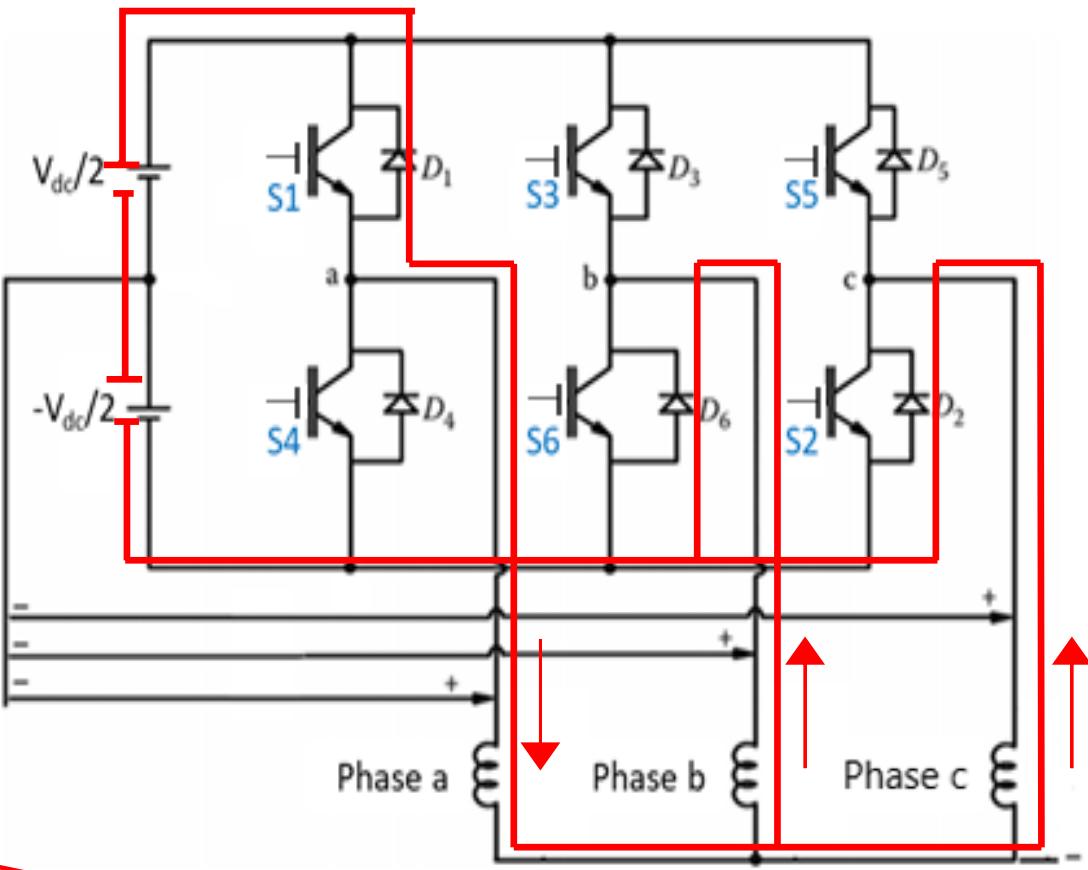
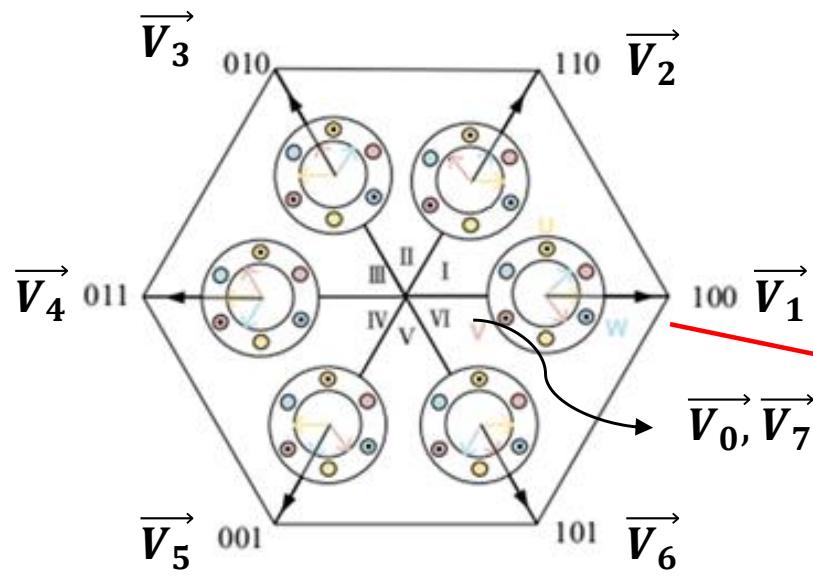
→ P.2(Control Architecture of FOC for PMSM)

The spacial positions of the standard voltage vectors $\vec{V}_0 \dots \vec{V}_7$ in stator-fixed $\alpha\beta$ coordinates in relation to the three windings a, b and c. The vectors divide the vector space into six sectors $S1 \dots S6$ and respectively into four quadrants $Q1 \dots Q4$



Principle of SVPWM

- V_{xn} (with $x = a, b, c$) represents the phase voltage of the x phase, V_{ab}, V_{bc}, V_{ca} represent line voltage
- n is the neutral point of the motor



$$V_{an} = 2V_{dc}/3$$

$$V_{bn}, V_{cn} = -V_{dc}/3$$

Table 5.2. The Standard Voltage Vectors and Logic State

No.	Switching state sequence	V_a	V_b	V_c	V_{ab}	V_{bc}	\vec{V}
\vec{V}_0	S2, S4, S6	0	0	0	0	0	0
\vec{V}_1	S6, S1, S2	$2V_{dc}/3$	$-V_{dc}/3$	$-V_{dc}/3$	V_{dc}	0	$2V_{dc}/3 \angle 0$
\vec{V}_2	S1, S2, S3	$V_{dc}/3$	$V_{dc}/3$	$-2V_{dc}/3$	0	V_{dc}	$2V_{dc}/3 \angle (\frac{\pi}{3})$
\vec{V}_3	S2, S3, S4	$-V_{dc}/3$	$2V_{dc}/3$	$-V_{dc}/3$	$-V_{dc}$	V_{dc}	$2V_{dc}/3 \angle (-\frac{\pi}{3})$
\vec{V}_4	S3, S4, S5	$-2V_{dc}/3$	$V_{dc}/3$	$V_{dc}/3$	$-V_{dc}$	0	$2V_{dc}/3 \angle (-\pi)$
\vec{V}_5	S4, S5, S6	$-V_{dc}/3$	$-V_{dc}/3$	$2V_{dc}/3$	0	$-V_{dc}$	$2V_{dc}/3 \angle (-\frac{2\pi}{3})$
\vec{V}_6	S5, S6, S1	$V_{dc}/3$	$-2V_{dc}/3$	$V_{dc}/3$	V_{dc}	$-V_{dc}$	$2V_{dc}/3 \angle (-\frac{\pi}{3})$
\vec{V}_7	S1, S3, S5	0	0	0	0	0	0

Principle of SVPWM

- Let us assume that the vector to be realized, V_s is located in the sector S1, the area between the standard vectors V_1 and V_2 . V_s can be obtained from the vectorial addition of the two boundary vectors V_r and V_l in the directions of V_1 and V_2 , respectively.
- Supposed the complete pulse period T_p^* is available for the realization of a vector with the maximum modulus (amplitude), which corresponds to the value $\underline{2V_{dc}/3}$ of a standard vector, the following relation is valid:

$$|V_s|_{\max} = |V_1| = \dots = |V_6| = 2V_{dc}/3$$

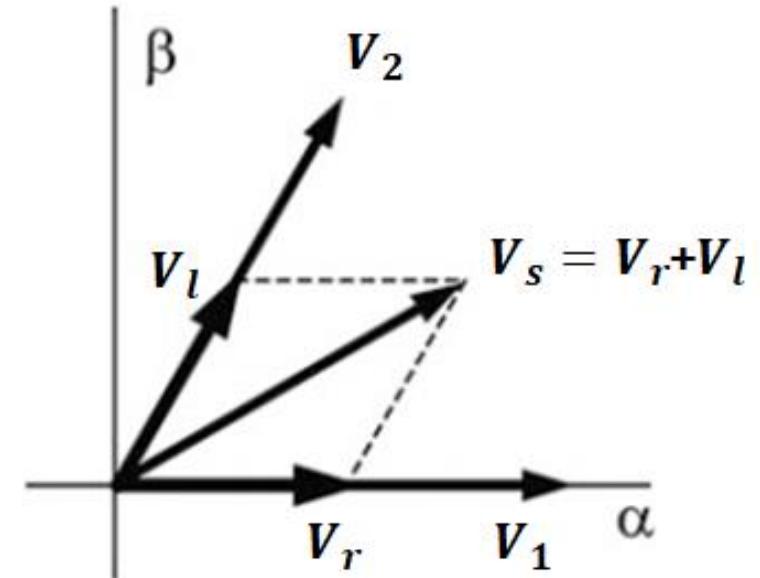
- V_r and V_l are realized by the logical states of the vectors V_1 and V_2 within the time span:

$$\underline{T_r = T_p^* \frac{|V_r|}{|V_s|_{\max}}} \quad \underline{T_l = T_p^* \frac{|V_l|}{|V_s|_{\max}}}$$

T_r , T_l are switching times must be calculated.

To be able to determine T_r and T_l , the amplitudes of V_r and V_l must be known.

(***Subscript r, l: boundary vector on the right, left)



Realization of an arbitrary voltage vector from two boundary vectors

Principle of SVPWM

- It is prerequisite that the stator voltage vector V_s must be provided by the current controller with respect to modulus and phase.
- In the rest of the pulse period $T_p^* - (T_r + T_l)$ one of the two zero vectors V_0 or V_7 will be issued to finally fulfil the following equation.

$$V_s = V_r + V_l + V_0 \text{ (or } V_7) = \frac{T_r}{T_p^*} V_1 + \frac{T_l}{T_p^*} V_2 + \frac{T_p^* - (T_r + T_l)}{T_p^*} V_0 \text{ (or } V_7)$$

- In which sequence the now three vectors—two boundary vectors and one zero vector—must be issued. Table shows the necessary switching states in the sector S1.

Table 5.3. The necessary switching states in the sector S1

Voltage	V_0	V_1	V_2	V_7
V_a	0	1	1	1
V_b	0	0	1	1
V_c	0	0	0	1

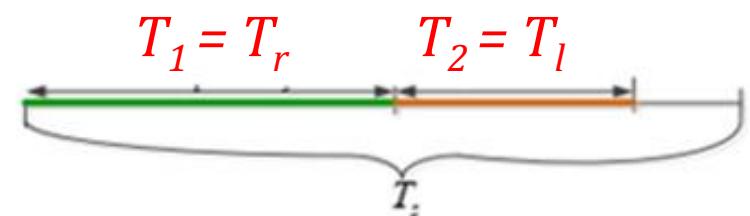
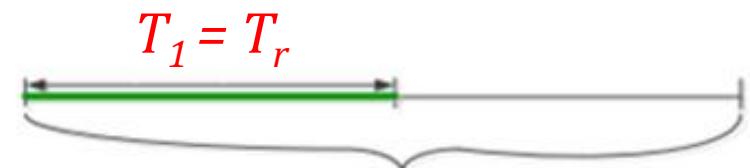
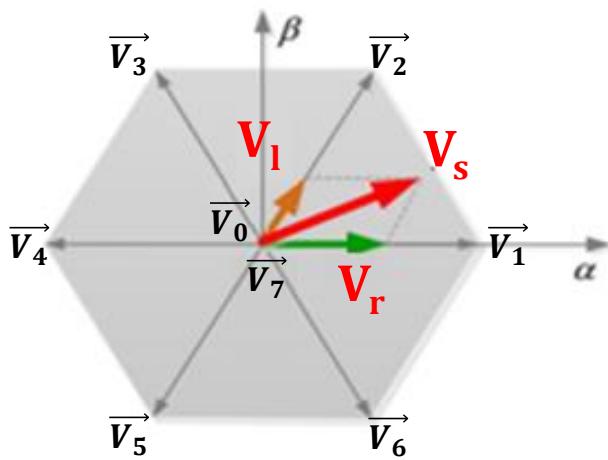
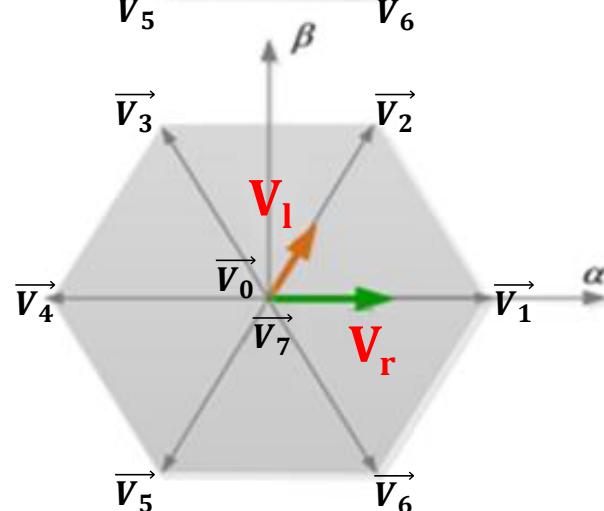
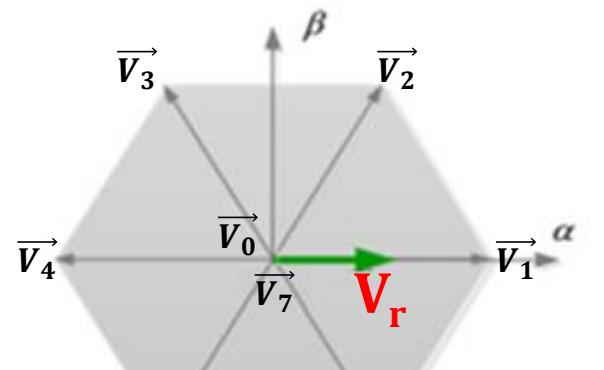
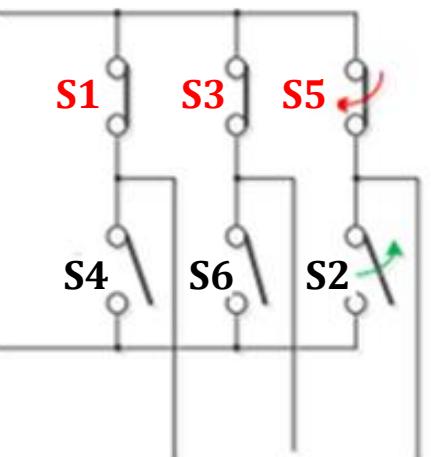
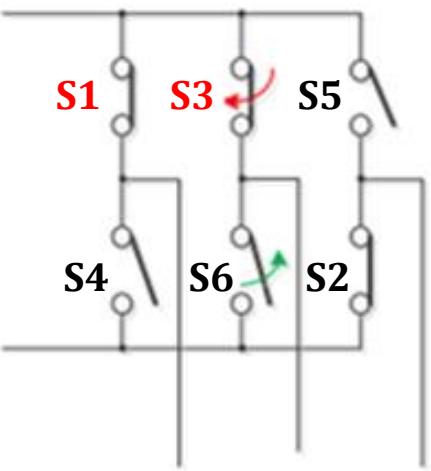
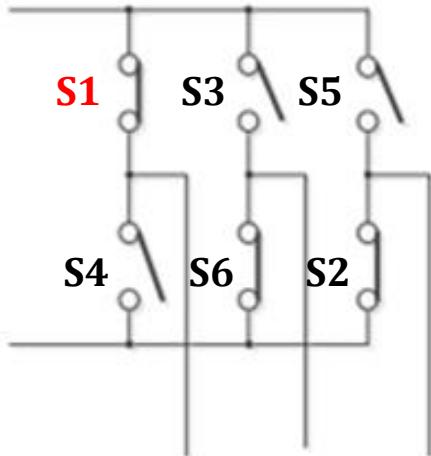
Principle of SVPWM

By observing “Table of switching states in the sector S1”, it can be recognized that with respect to transistor switching losses the most favourable sequence is to switch every transistor pair only once within a pulse period.

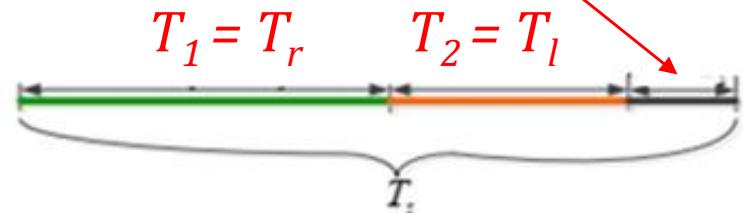
If the last switching state was V_0 , this would be the sequence $V_0 \rightarrow V_1 \rightarrow V_2 \rightarrow V_7$

But if the last switching state was V_7 , this would be $V_7 \rightarrow V_2 \rightarrow V_1 \rightarrow V_0$

→ ***With this strategy the switching losses of the inverter become minimal.***

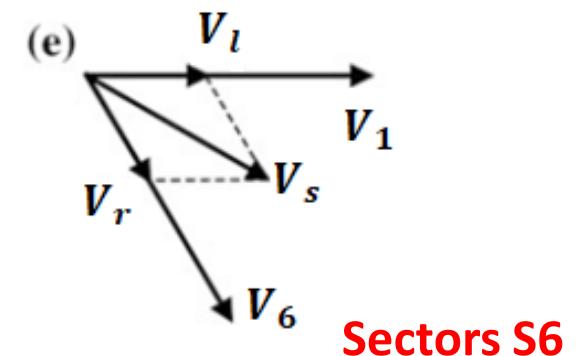
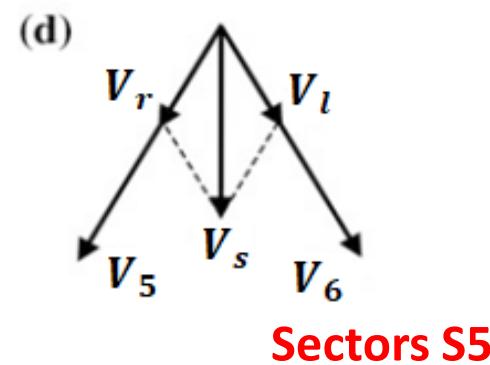
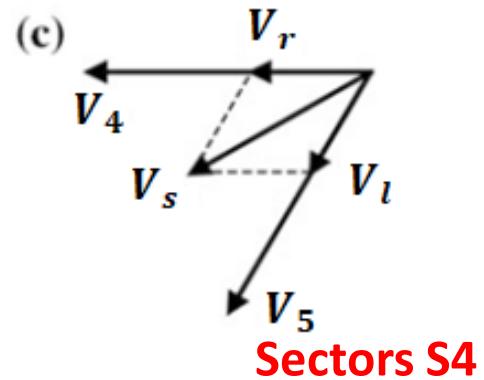
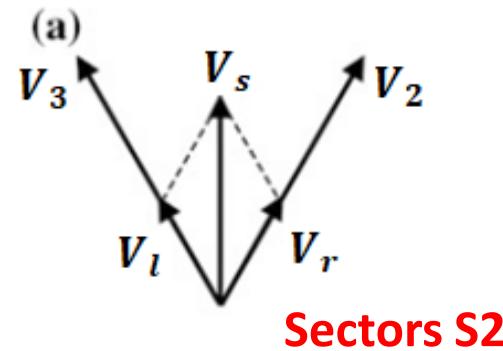
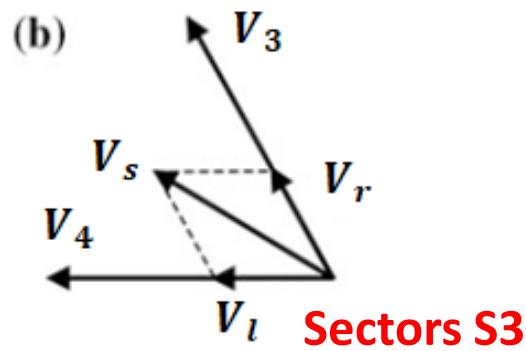


$$T_0(T_7) = T_p^* - (T_r + T_l)$$



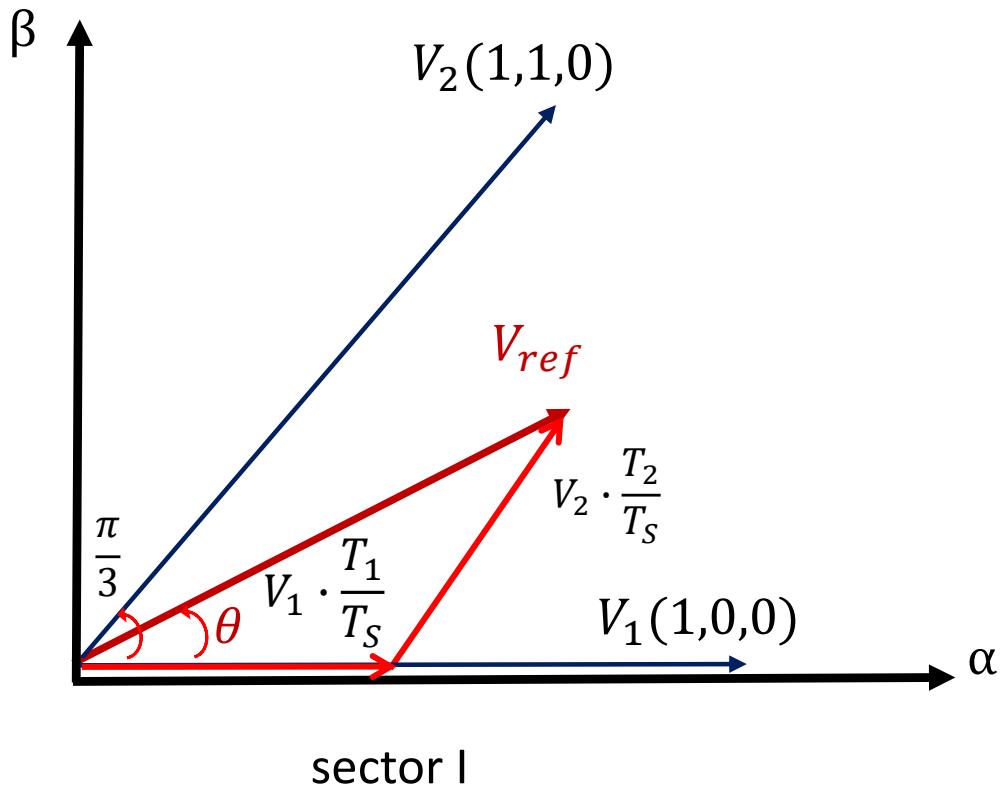
Principle of SVPWM

- The following pictures give a summary of switching pattern samples in the remaining sectors S2 ... S6 of the vector space



*Pulse pattern of the voltage vectors
in the sectors S2 ... S6*

Determined Switching Time



$$V_1 = \frac{2}{3} V_{dc}$$

$$V_2 = \frac{2}{3} V_{dc} e^{i\frac{\pi}{3}}$$

$$|V_{ref}| = \frac{1}{\sqrt{3}} V_{dc}$$

V_{ref} is a rotating space voltage vector

In sector I, $V_{ref} \cdot T_S = V_1 \cdot T_1 + V_2 \cdot T_2$

T_S : carrier period

$$\begin{bmatrix} |V_{ref}| \cdot \cos\theta \\ |V_{ref}| \cdot \sin\theta \end{bmatrix} = \begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \begin{bmatrix} \frac{T_1}{T_S} & \cos \frac{\pi}{3} \cdot \frac{T_2}{T_S} \\ 0 & \sin \frac{\pi}{3} \cdot \frac{T_2}{T_S} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

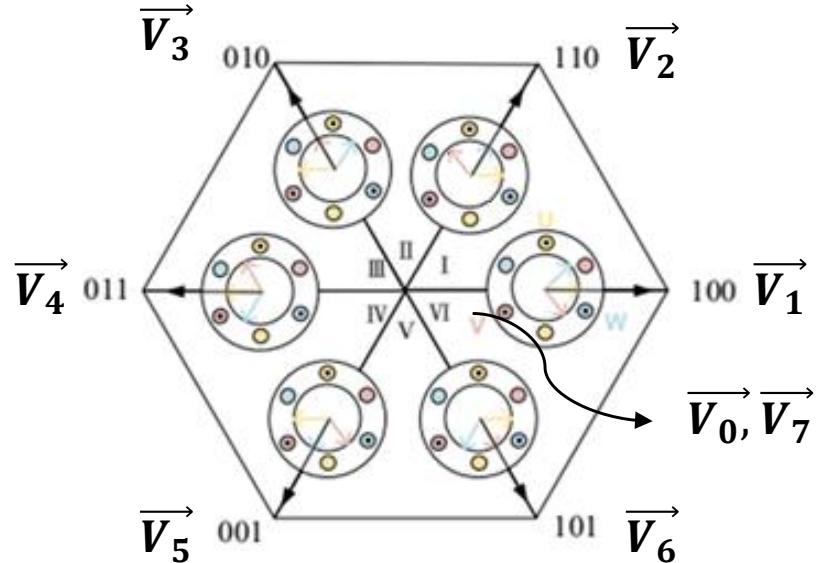
$$\frac{T_1}{T_S} = \sin\left(\frac{\pi}{3} - \theta\right)$$

$$\frac{T_2}{T_S} = \sin(\theta)$$

$$\frac{T_1}{T_S} = \frac{1}{V_{dc}} \left(\frac{3}{2} \cdot V_\alpha - \frac{\sqrt{3}}{2} \cdot V_\beta \right)$$

$$\frac{T_2}{T_S} = \sqrt{3} \cdot \frac{V_\beta}{V_{dc}}$$

Determined Switching Time



$$X = \frac{1}{V_{dc}} \cdot V_\beta \cdot \sqrt{3}$$

$$Y = \frac{1}{V_{dc}} \cdot \left(\frac{3}{2} V_\alpha + \frac{\sqrt{3}}{2} V_\beta \right)$$

$$Z = \frac{1}{V_{dc}} \cdot \left(\frac{3}{2} V_\alpha - \frac{\sqrt{3}}{2} V_\beta \right)$$

Table 5.4. Look-up table of sector number

Sector number	I	II	III	IV	V	VI
T_x	Z	Y	X	-Z	-Y	-X
T_y	X	-Z	-Y	-X	Z	Y

T_x :the application time of the first active vector

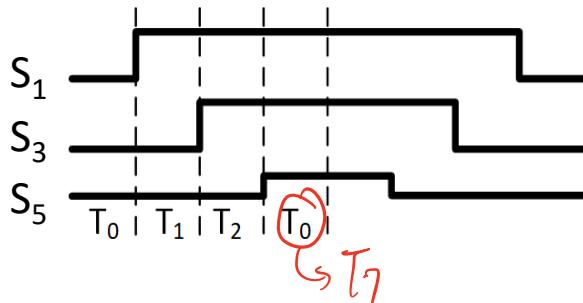
T_y :the application time of the second active vector

Determined Switching Time

[P.2\(Control Architecture of FOC for PMSM\)](#)

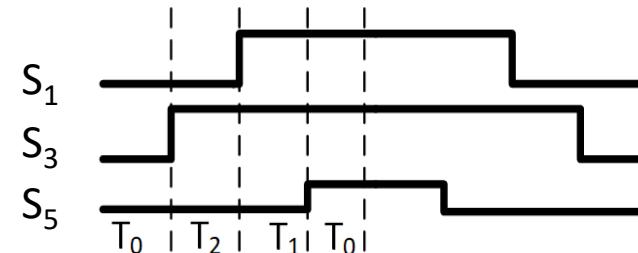
[P.45\(Dynamic animation\)](#)

Sector I



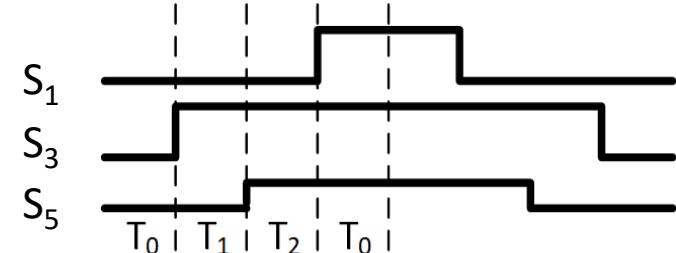
$$\begin{aligned}S_1 &= T_1 + T_2 + T_0 \\S_3 &= T_2 + T_0 \\S_5 &= T_0\end{aligned}$$

Sector II



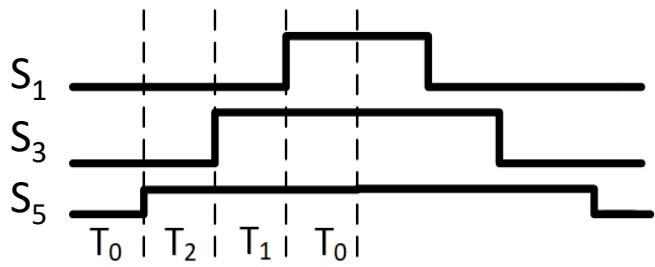
$$\begin{aligned}S_1 &= T_1 + T_0 \\S_3 &= T_1 + T_2 + T_0 \\S_5 &= T_0\end{aligned}$$

Sector III



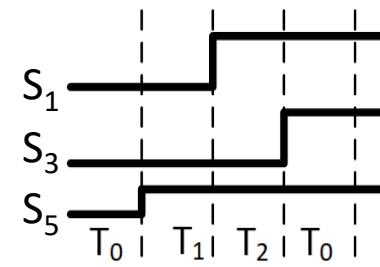
$$\begin{aligned}S_1 &= T_0 \\S_3 &= T_1 + T_2 + T_0 \\S_5 &= T_2 + T_0\end{aligned}$$

Sector IV



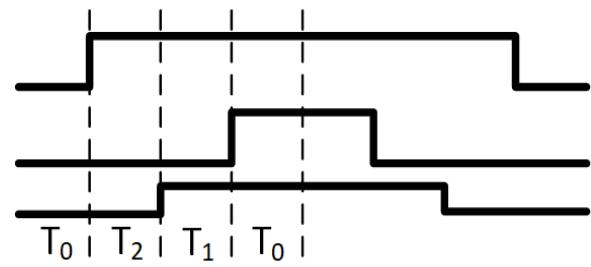
$$\begin{aligned}S_1 &= T_0 \\S_3 &= T_1 + T_0 \\S_5 &= T_1 + T_2 + T_0\end{aligned}$$

Sector V



$$\begin{aligned}S_1 &= T_2 + T_0 \\S_3 &= T_0 \\S_5 &= T_1 + T_2 + T_0\end{aligned}$$

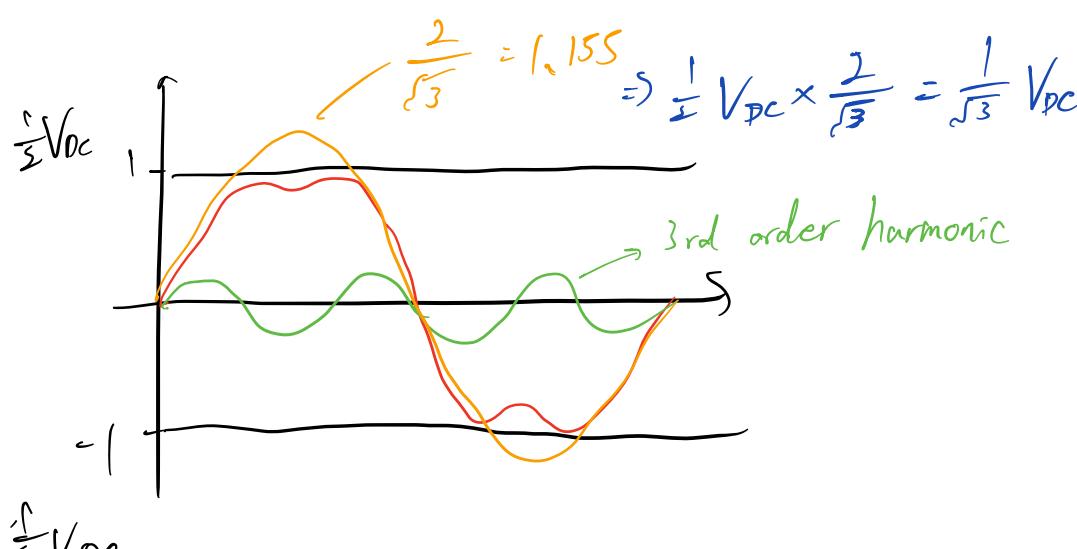
Sector IV



$$\begin{aligned}S_1 &= T_1 + T_2 + T_0 \\S_3 &= T_0 \\S_5 &= T_1 + T_0\end{aligned}$$

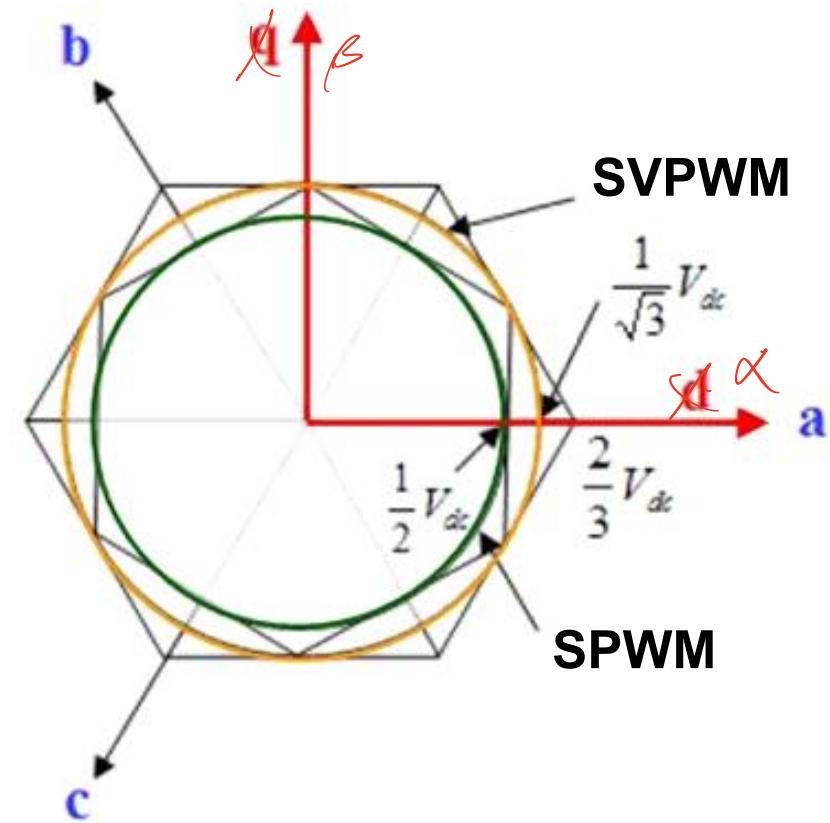
Comparison of SPWM and SVPWM

- Sinusoidal PWM (SPWM) : Locus of the reference vector is the inside of a circle with radius of $1/2 V_{dc}$
- Space Vector PWM (SVPWM) : Locus of the reference vector is the inside of a circle with radius of $1/\sqrt{3} V_{dc}$

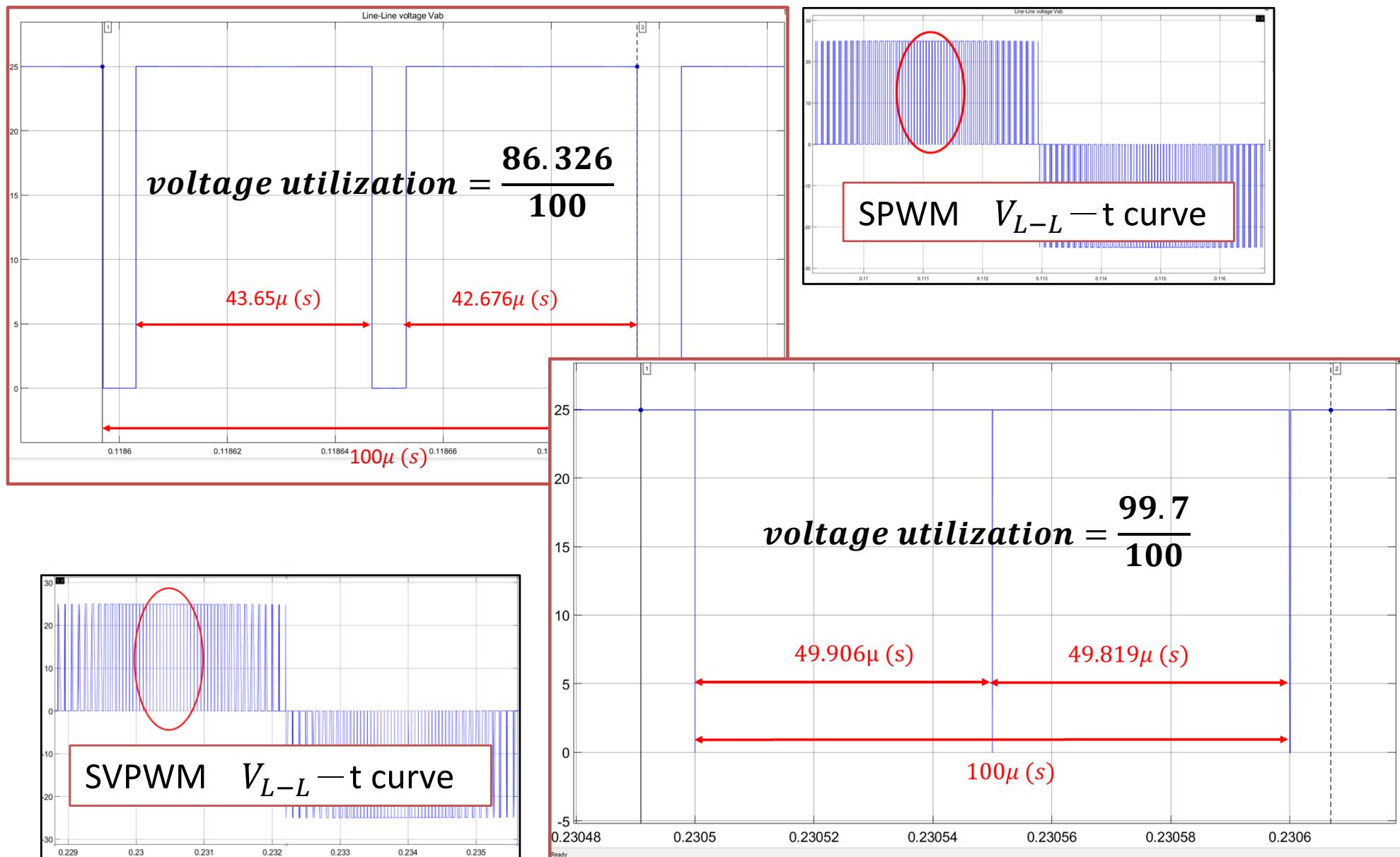


$$V(t) = \frac{2}{\sqrt{3}} \left(\cos \omega t - \frac{1}{6} \cos (3\omega t) \right)$$

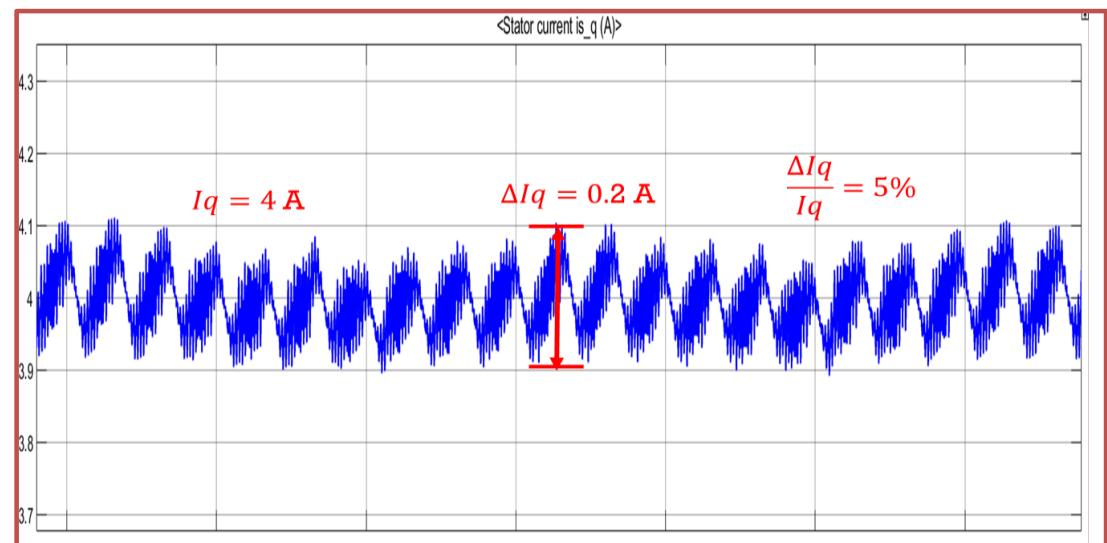
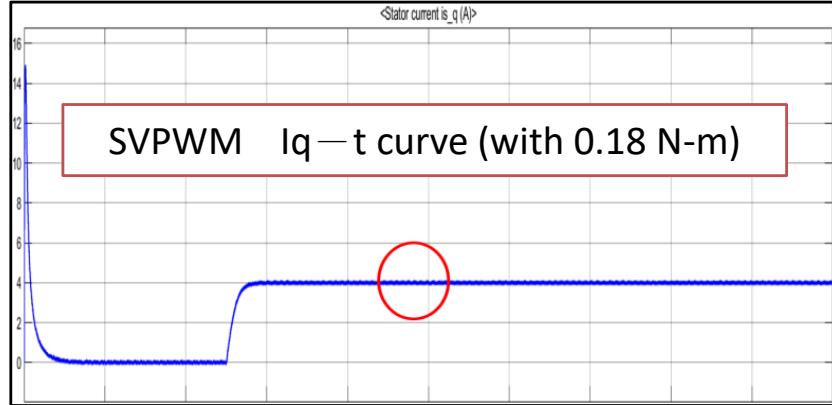
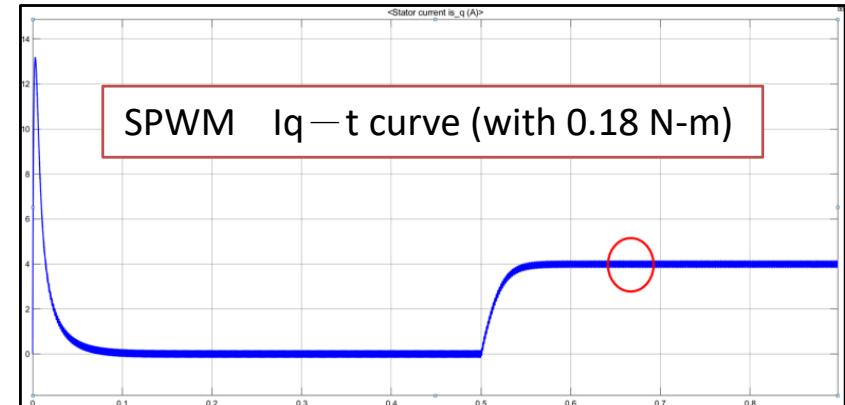
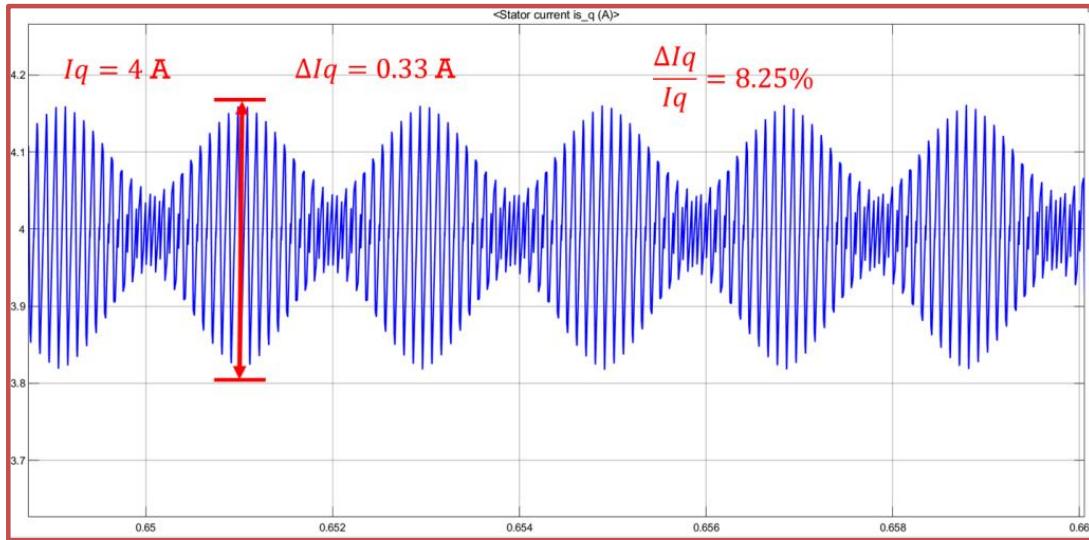
fundamental



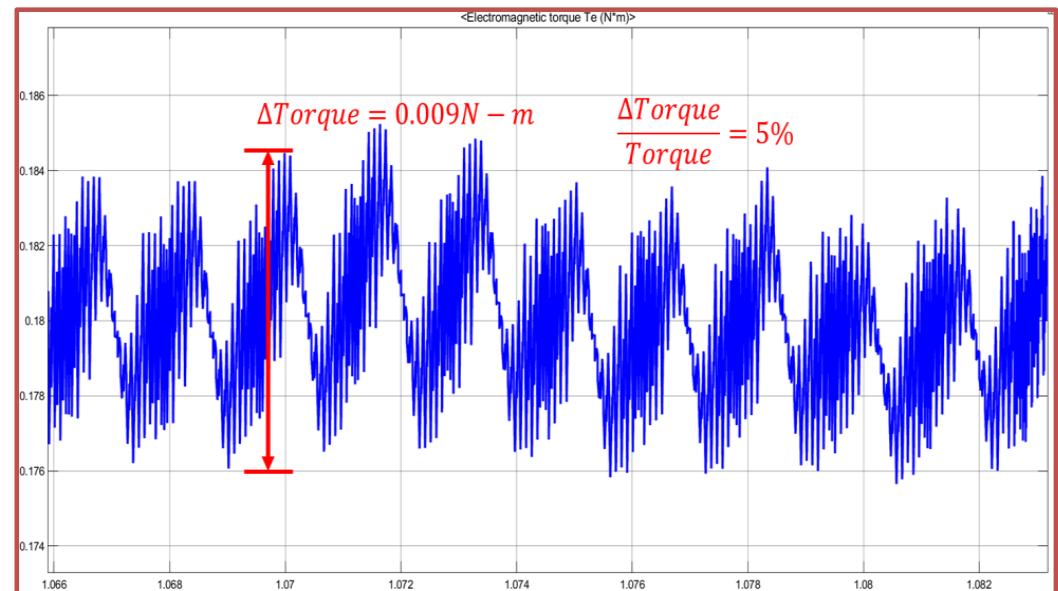
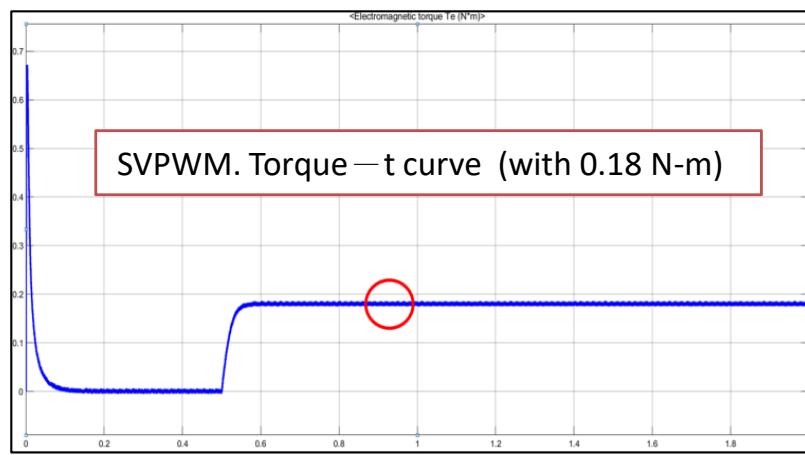
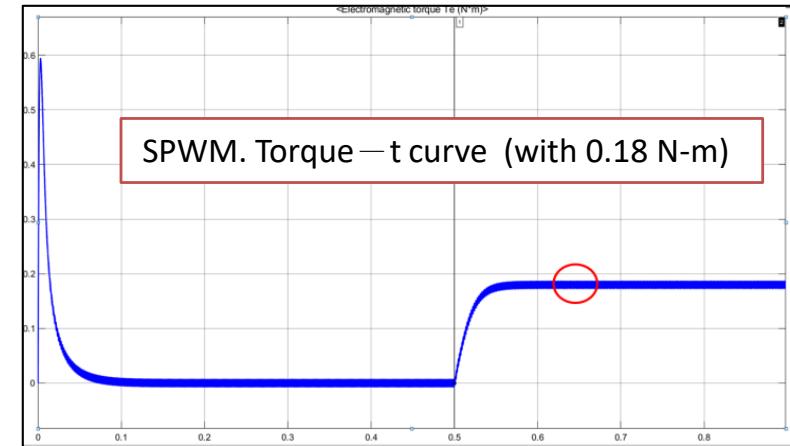
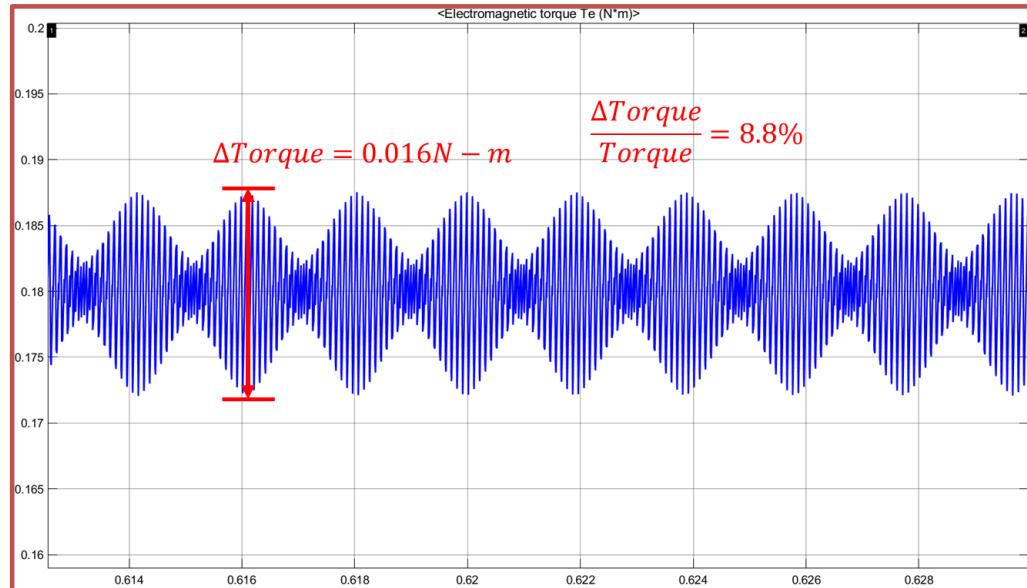
Comparison of SPWM with SVPWM



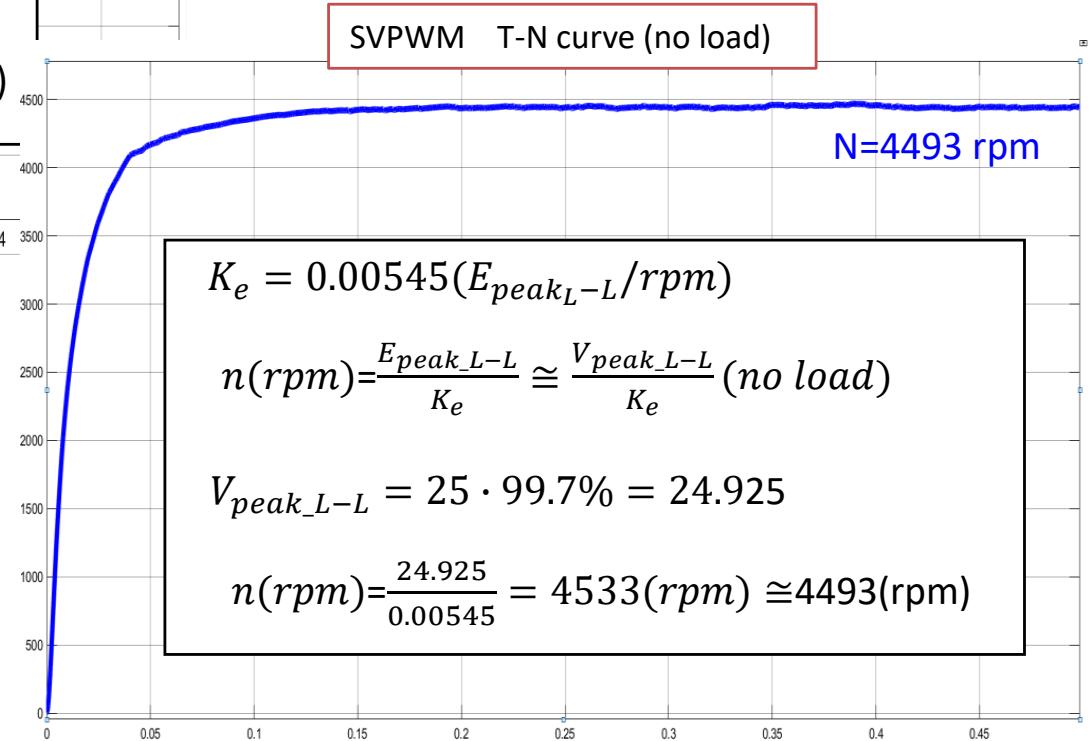
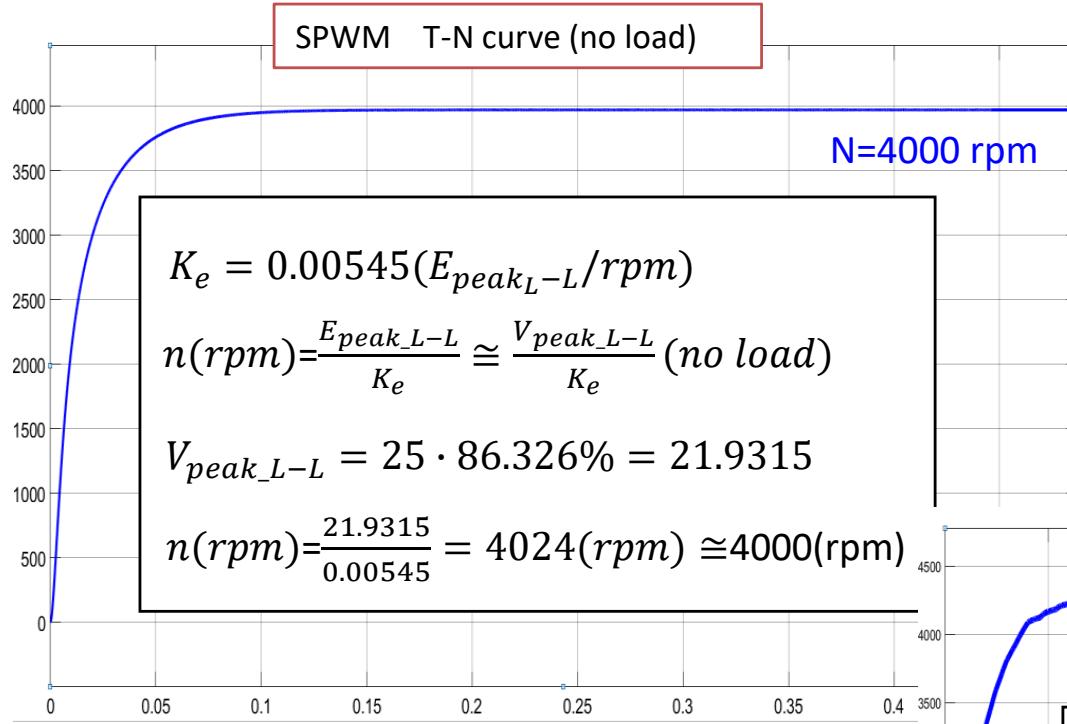
Comparison of SPWM with SVPWM



Comparison of SPWM with SVPWM



Comparison of SPWM with SVPWM



Comparison of SPWM and SVPWM

Table 5.5. Result of “Simulation of Compare SPWM with SVPWM”,

Item.	SPWM	SVPWM
Voltage utilization	86.326%	99.7%
Speed (no-load)	4000 (rpm)	4493 (rpm)
Torque ripple	8.8%	5%
Current(I_q) ripple	8.25%	5%

- Space Vector PWM generates less harmonic distortion in the output voltage or currents in comparison with sinusoidal PWM.
- Space Vector PWM provides more efficient use of supply voltage in comparison with Sinusoidal PWM
- SPWM can be used for the application where a small compromise can be done with output quality and the application requirements are less complexity. But where better performance with high output quality is desired the choice should be SVPWM.



P.38(Determined Switching Time)

