ITMO

Actuators

Laboratory work №6
AC drive converters: PWM basics

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Pulse Width Control at Base Frequency

The figure shows the dependencies of ratio of the carrier frequency to the fundamental frequency

$T_S / \tau_{SW} = f_{sw}/f_s = m_f$ =2 for this case

Herewith $K_{harm_N} = \frac{1}{\nu}\frac{\sin(\nu\pi\gamma/6m_f)}{\sin(\nu\pi/6m_f)}$

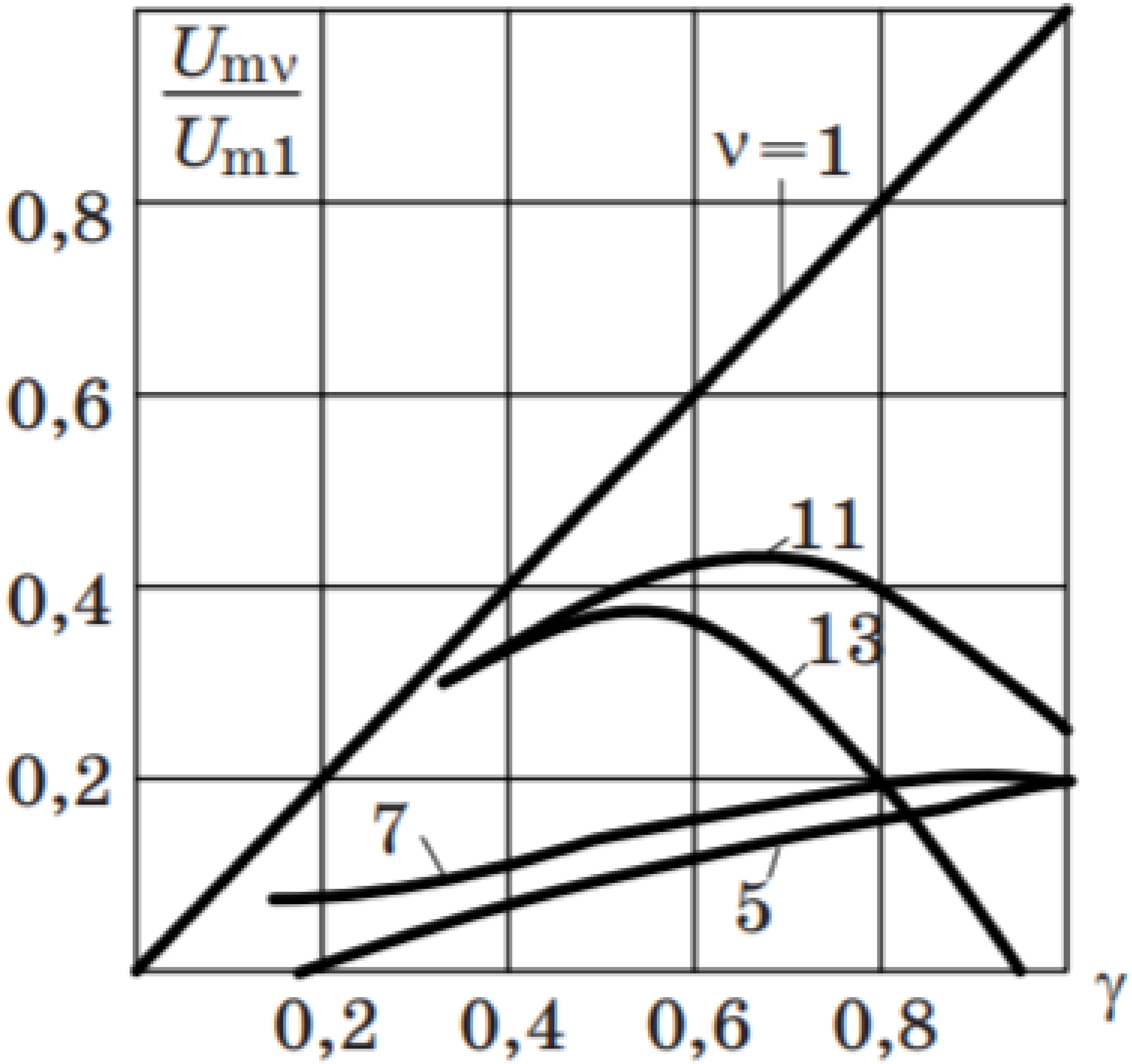
This expression shows that for the monotonous descending of the harmonic - $\frac{\nu}{m_f} \leq 3$

At m_f =1 this condition is not met

m_f =2 It is performed for 5 harmonics

m_f =3 for 5 and 7 harmonics... etc.

Thus, with an increase in m_f , it is possible to achieve a monotonous decrease in the relative amplitude of any harmonic. At the same time, the amplitudes of smaller harmonics will also decrease. Unfortunately, at the same time, harmonics of high orders will increase.



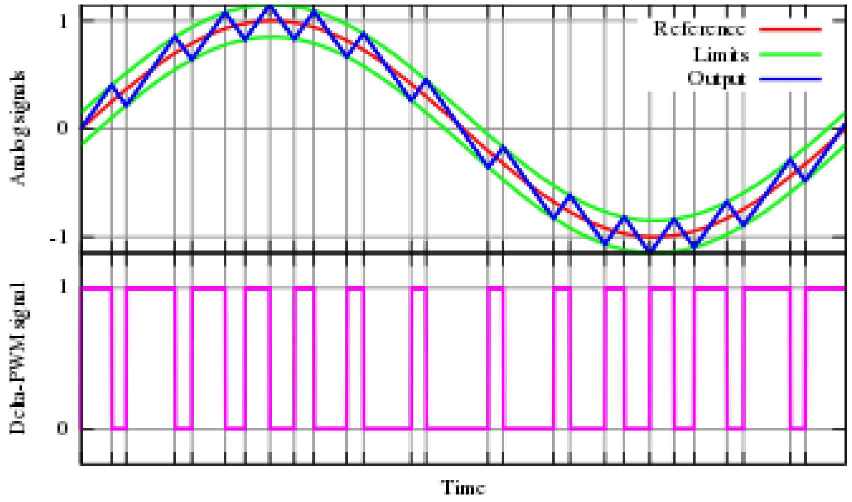
ITMO

Actuators

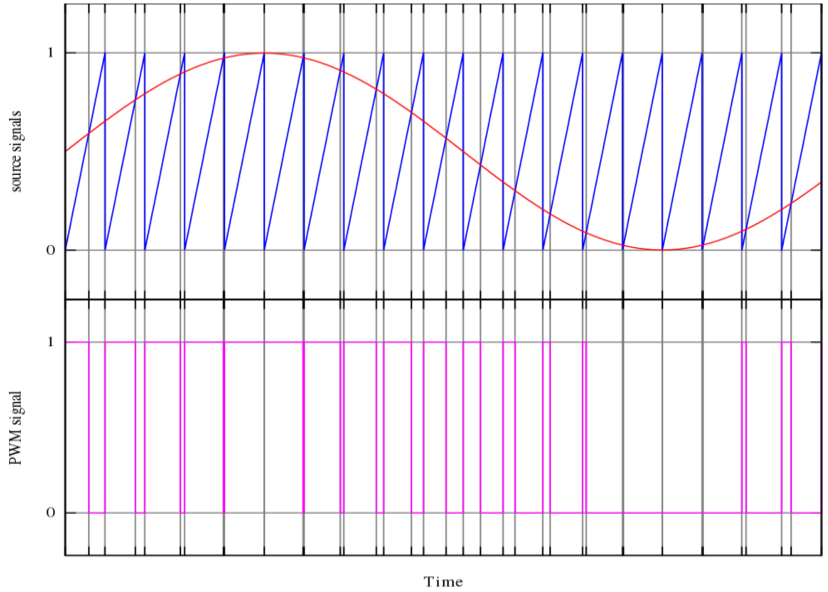
Pulse-Width Modulation

in inverters of AC electric drive systems

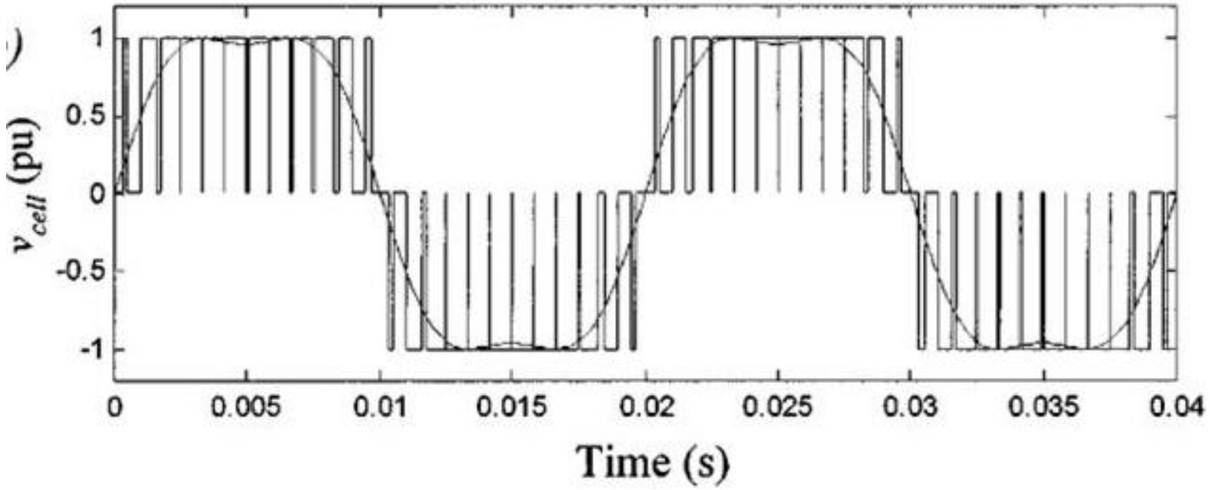
- hysteresis or delta modulation;
- analog (scalar) Sine PWM and its modifications;
- selective suppression of higher harmonics;
- space vector modulation (SVM / SVPWM). СШИМ



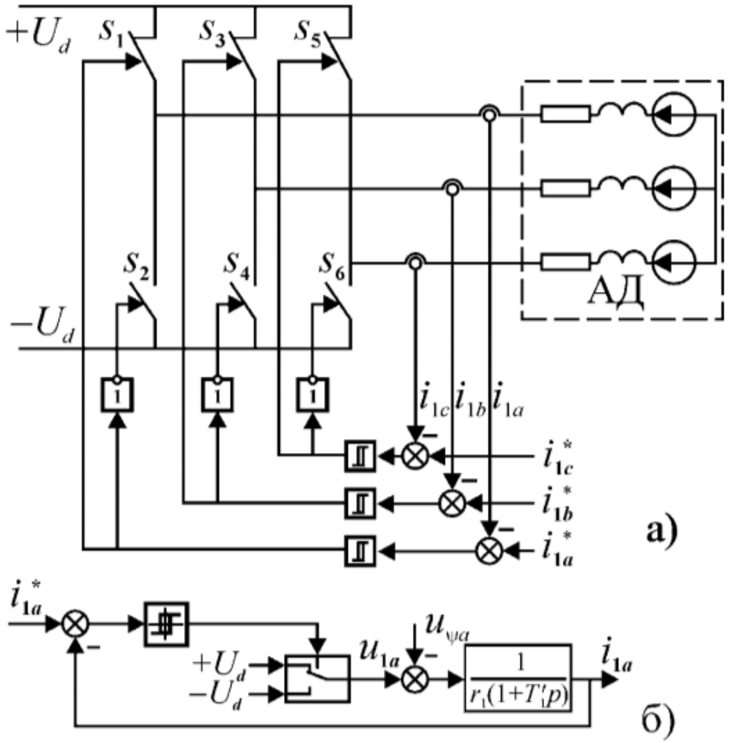
Delta modulation

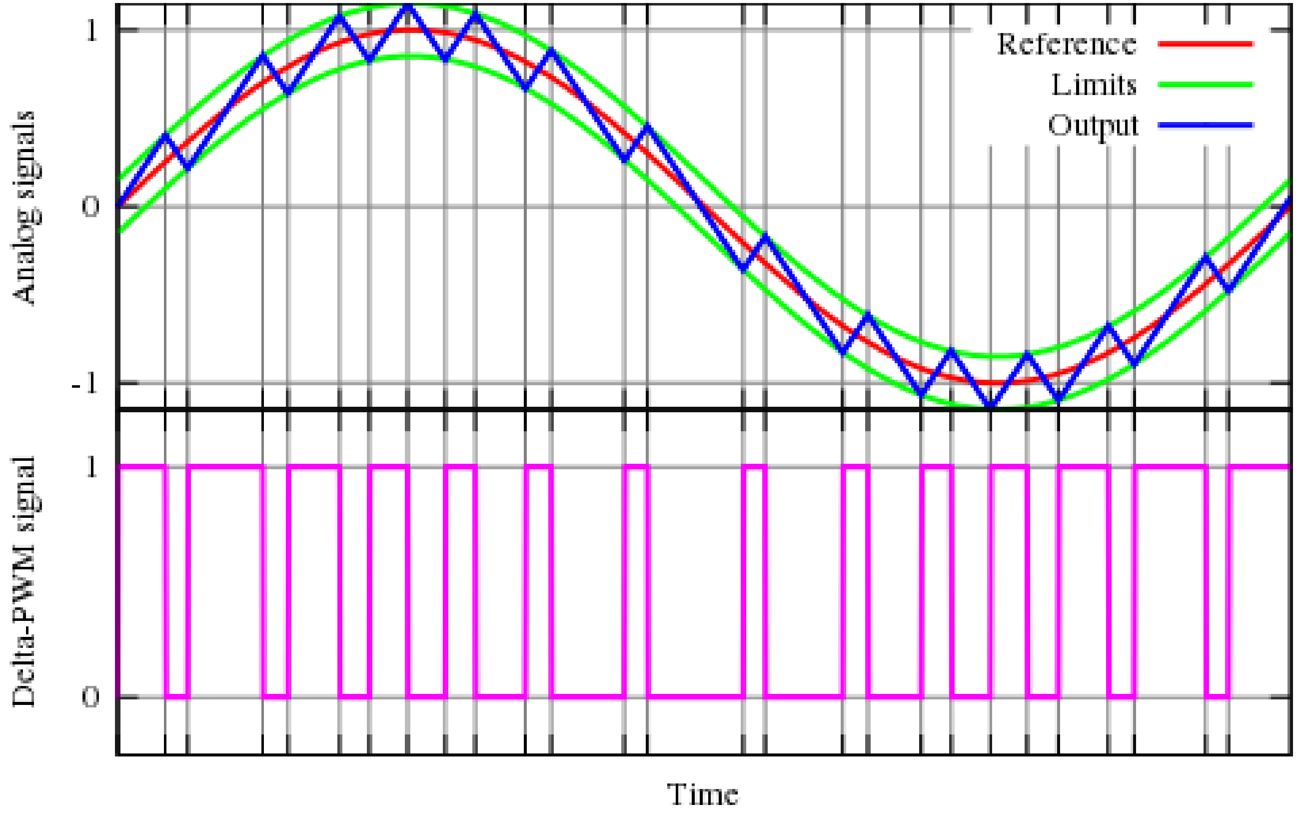


Sine PWM



Output voltage with the addition of a sinusoidal third harmonic

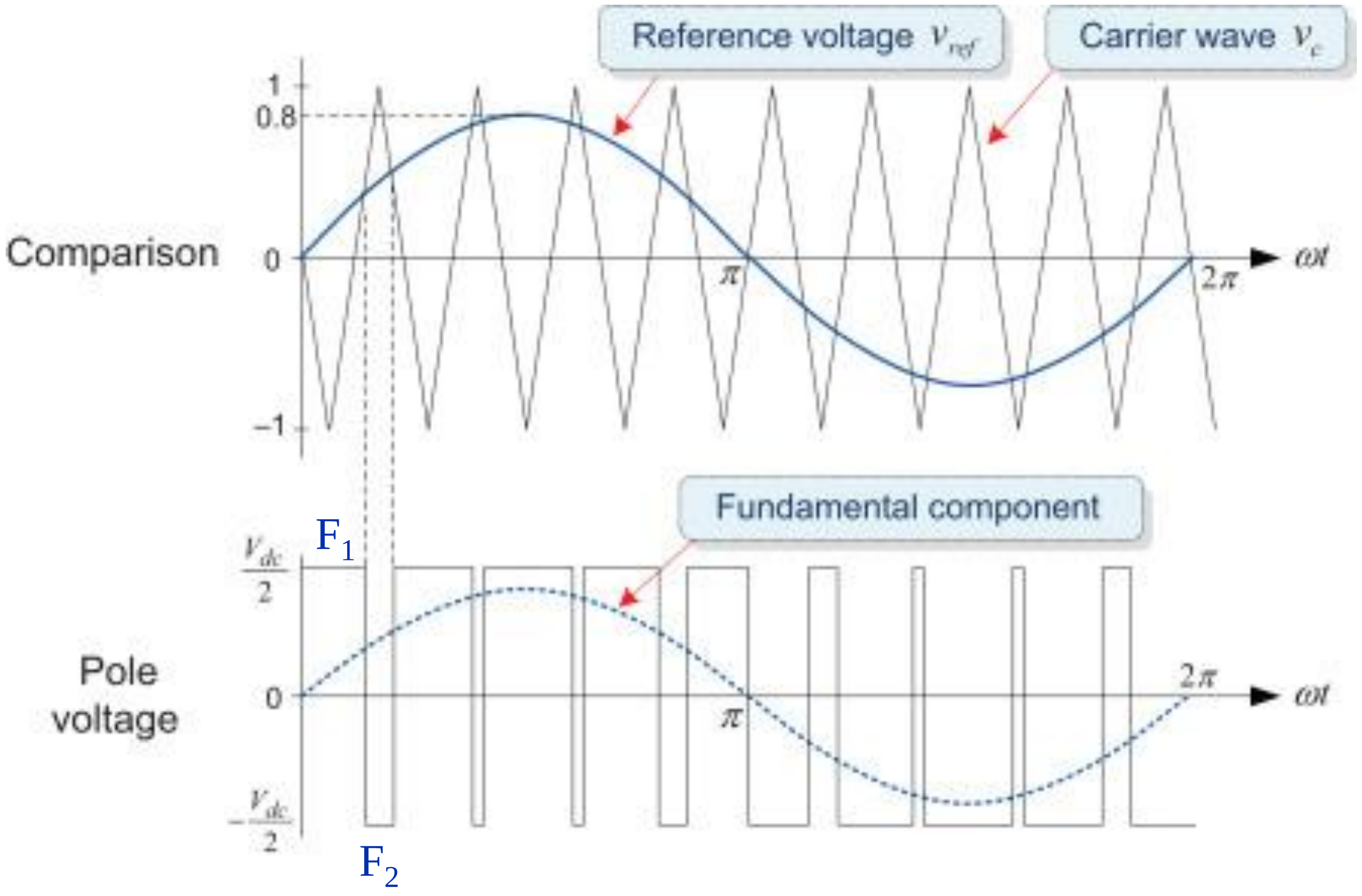




The method can be reduced to "tracking" the current in the region of permissible deviations from the current value of the set or reference signal.

Each of the three (according to the number of phases of the inverter) regulators has a hysteresis characteristic.

Reference signals are sinusoidal signals for setting phase currents with which



The inverter control system contains:

- carrier voltage generator (most often - sawtooth);

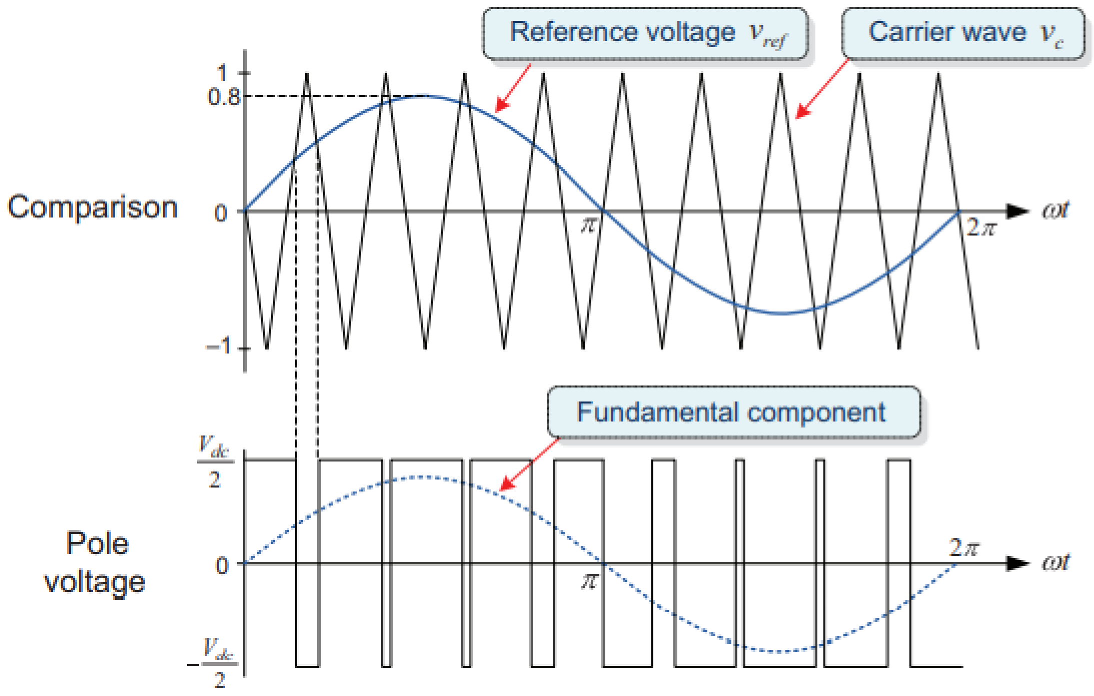
- Comparator K (null organ);

- F_1 and F_2 control signal generators, VT1 and VT2 transistors, respectively.

Pulse Width Control at Base Frequency

Modulation index: $MI = \frac{U_{s_{peak}}}{{}^{1}/_{2}U_{dc}}$

Frequency modulation index: $m_f = f_{sw}/f_s$

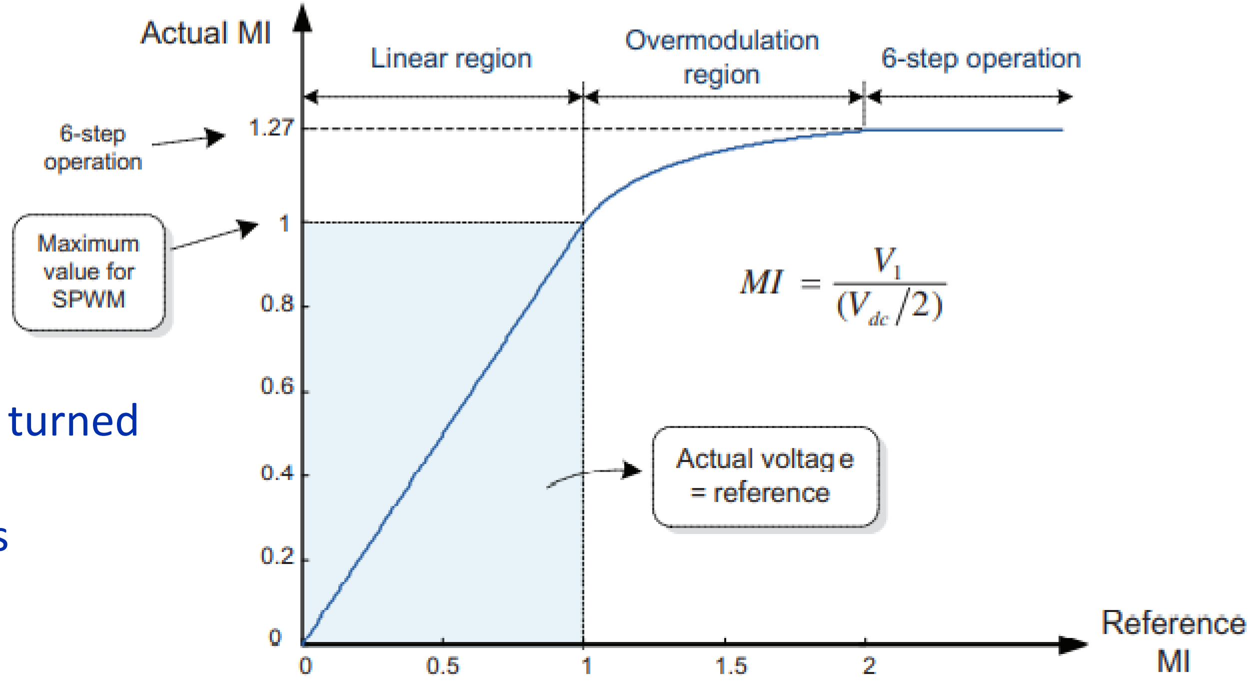


Voltage reference v_{ref} >Triangular carrier v_c: upper switch is turned on (pole voltage = $V_{dc}/2$)

Voltage reference v_{ref} <Triangular carrier v_c : lower switch is turned on (pole voltage =- $V_{dc}/2$)

U_s - AC induction motor stator phase voltage (RMS) [V]
E_s - AC induction motor stator phase voltage back-EMF (RMS) [V]
Φ_s - magnetic flux [Wb]
f_s - stator phase voltage frequency [Hz]
w_s - stator winding number
λ - overload capacity
T_{est} - starting torque [N*m]
$T_{e_{rated}}$ - rated torque of the machine [N*m]
ω_{rated} - rated angular velocity of the machine [rad/s]
n_{rated} - rated rotating velocity of the machine [rpm]
z_p - pole pair number

$$v_{ref}\sin(f_s \cdot 2 \cdot \pi \cdot t) = U_s = {}^{1}/_{2}\,U_{dc} MI \sin(\omega_s \cdot t)$$



Pulse Width Control at Base Frequency

Modulation index: $MI = \frac{U_{s_{peak}}}{1/_2 U_{dc}}$

Frequency modulation index: $m_f = f_{sw}/f_s$

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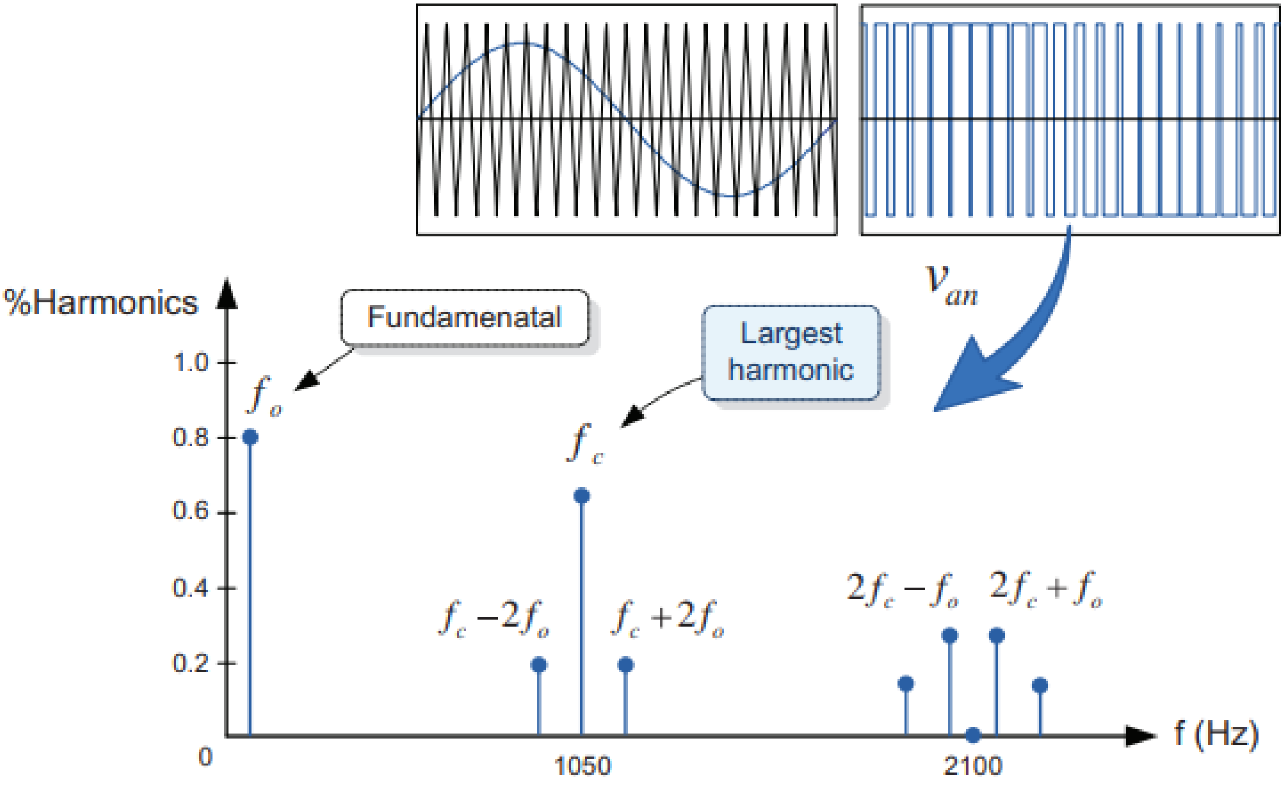


$m_f,\ m_f \pm 2,\ m_f \pm 4,\ m_f \pm 6, \ldots$

$2m_f \pm 1,\ 2m_f \pm 3,\ 2m_f \pm 5,\ 2m_f \pm 7, \ldots$

$3m_f,\ 3m_f \pm 2,\ 3m_f \pm 4,\ 3m_f \pm 6, \ldots$

$4m_f \pm 1,\ 4m_f \pm 3,\ 4m_f \pm 5,\ 4m_f \pm 7, \ldots$

$f_0 = 50Hz$

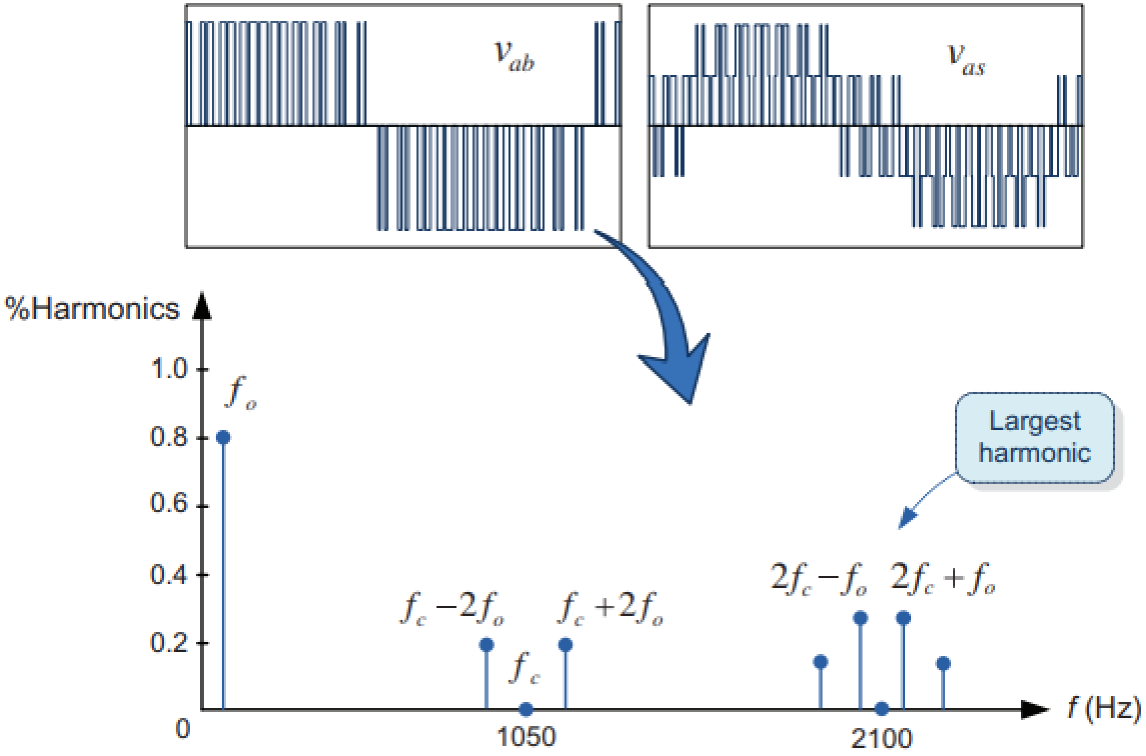
$f_{sw} = f_c = 1050\text{Hz}$

$m_f = f_c/f_0 = 21$

Pulse Width Control at Base Frequency

Modulation index: $MI = \frac{U_{s_{peak}}}{1/2 U_{dc}}$

Frequency modulation index: $m_f = f_{sw}/f_s$



U_s - AC induction motor stator phase voltage (RMS) [V]
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$$m_f,\ m_f \pm 2,\ m_f \pm 4,\ m_f \pm 6, \ldots$$
$$2m_f \pm 1,\ 2m_f \pm 3,\ 2m_f \pm 5,\ 2m_f \pm 7, \ldots$$
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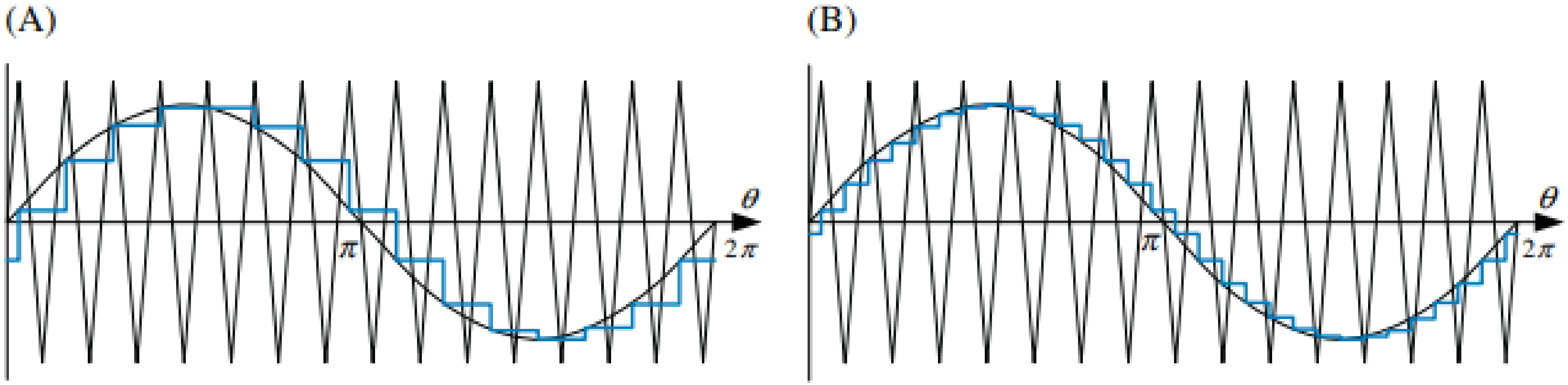
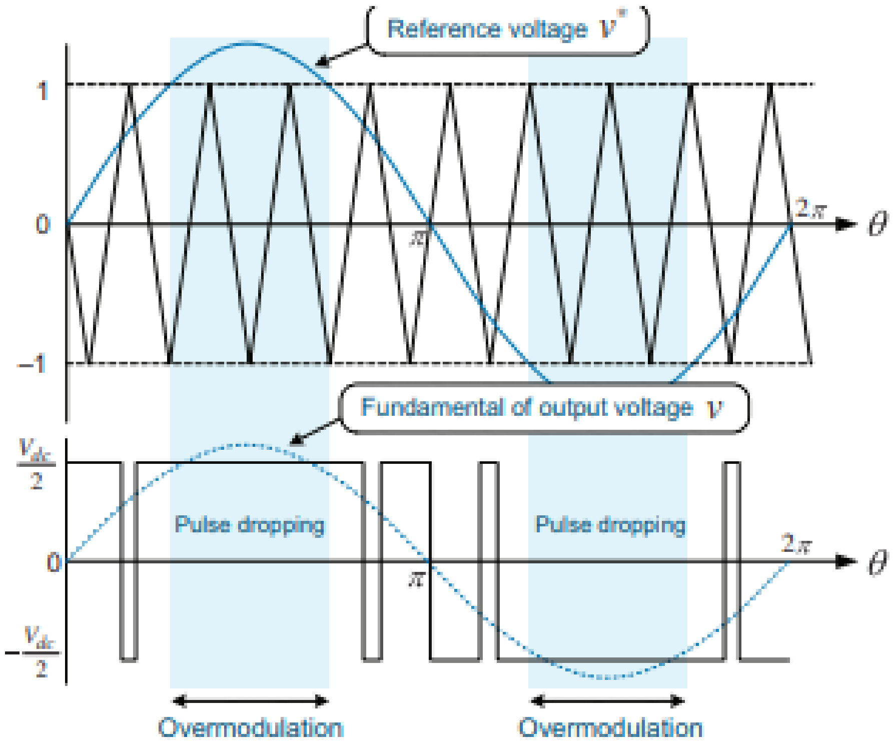
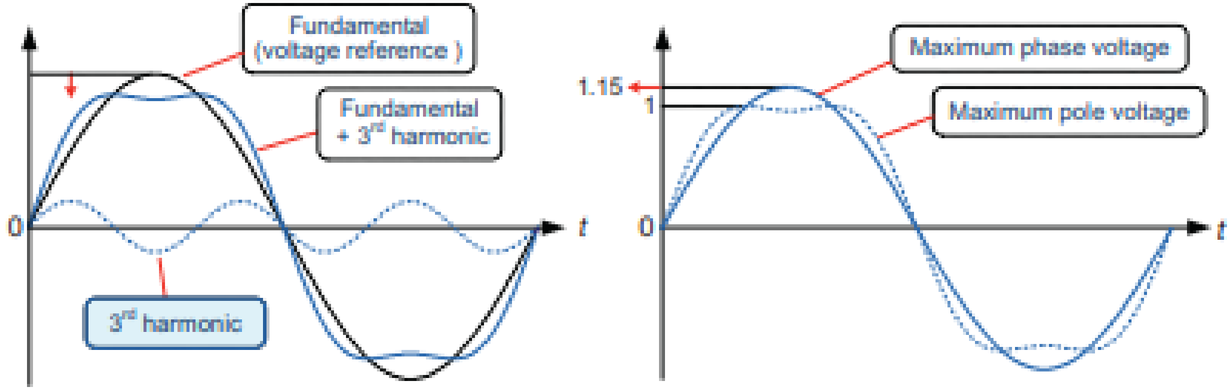
$$4m_f \pm 1,\ 4m_f \pm 3,\ 4m_f \pm 5,\ 4m_f \pm 7, \ldots$$

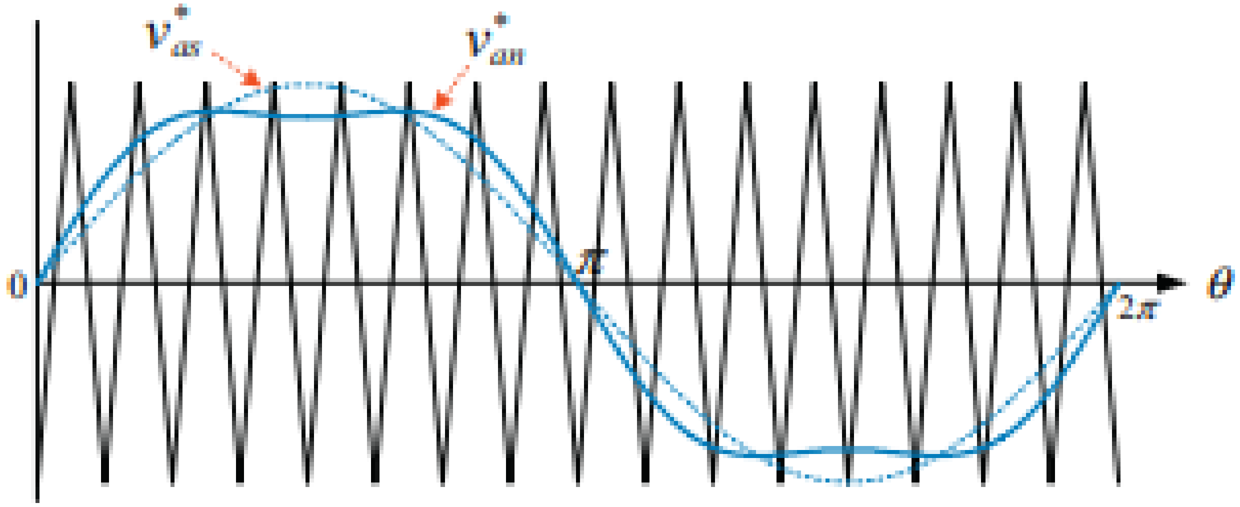
$$f_0 = 50Hz$$
$$f_{sw} = f_c = 1050\text{Hz}$$
$$m_f = f_c/f_0 = 21$$



Symmetrically sampling and (B) asymmetrically sampling


Reference voltage v^*
1
0
−1
π
2π
θ
Fundamental of output voltage v
$\frac{V_{dc}}{2}$
$-\frac{V_{dc}}{2}$
Pulse dropping
Pulse dropping
Overmodulation
Overmodulation


Fundamental (voltage reference)
Fundamental + 3rd harmonic
3rd harmonic
0
t
1.15
1
Maximum phase voltage
Maximum pole voltage


v_{as}^*
v_{an}^*
0
π
2π
θ

- ✓ LAB#6 is aimed at study Sine PWM and Delta PWM
- ✓ LAB#6 is performed in MATLAB / Simulink
- **Task :** Perform simulation with sine wave PWM. Compare ideal and converter power sources
  1. Define T_{erated},
  2. Provide speed-torque transient for ideal and converter cases with the first required rated speed n_{rated} and the second required reference speed n_{ref} and calculated torque T_{erated}
  3. Analyze the harmonic spectrum of line voltage U_{ab} and phase voltage U_{ag} and phase current I_a for both n_{rated} and n_{ref} cases
- Draw conclusions

1.1 Provide speed-torque transients with fundamental frequency f_e (sine wave PWM, ideal source + converter source)

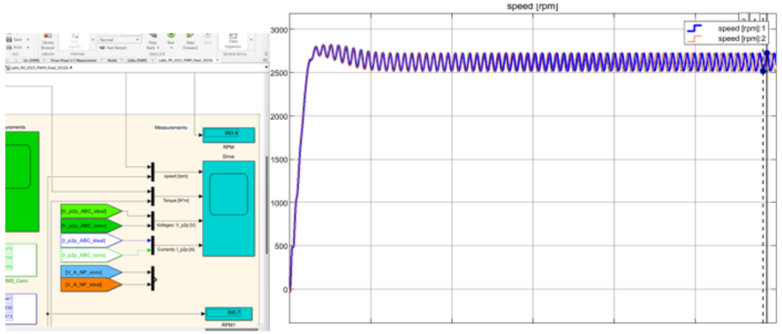


Figure 1 - Mechanical characteristics - for sine wave modulation at nominal (rated) n_{rated} speed with ideal source

1.2 Provide sine-wave PWM results for the with fundamental frequency f_e (sine wave PWM, ideal source + converter source)

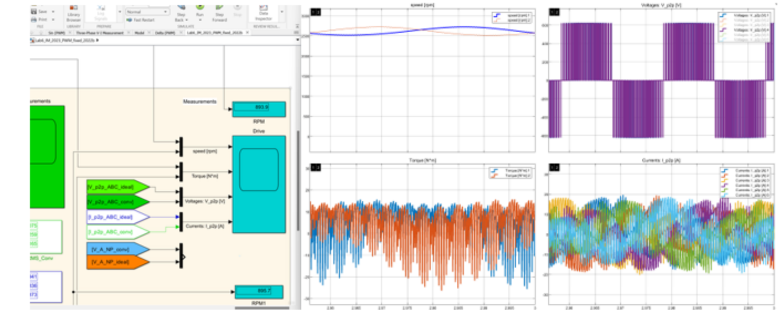


Figure 2 - Mechanical characteristics and PWM sine wave modulation at nominal (rated) speed n_{rated} with real converter and ideal source

1.3 Provide speed-torque transients at the second required speed with fundamental frequency f_{ref} (sine wave PWM, ideal source + converter source)

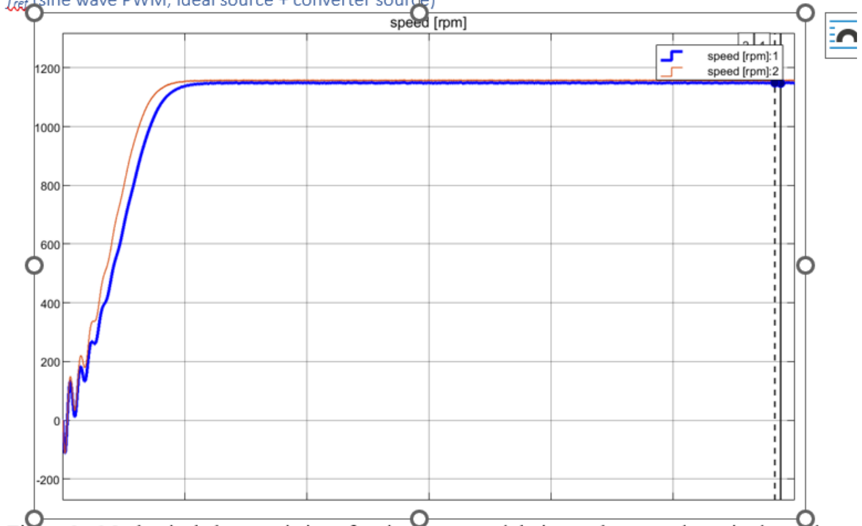


Figure 3 - Mechanical characteristics - for sine wave modulation at the second required speed n_{ref} speed with real converter and ideal source

1.4 Provide sine-wave PWM results for the second required speed with fundamental frequency f_{ref} (sine wave PWM, ideal source + converter source)

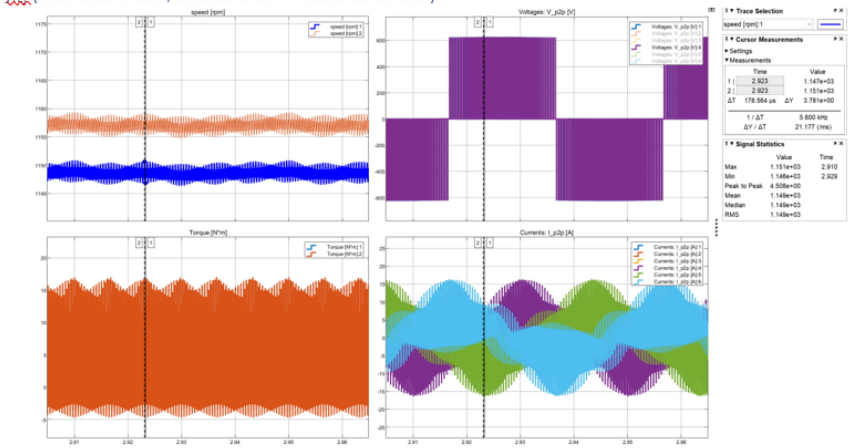


Figure 4 - Mechanical characteristics and PWM sine wave modulation at the second required speed n_{ref} with real converter and ideal source

Lab 6 report:

clck.ru/34cG7s

1st deadline – today!

2nd deadline – 12/04/2025 23.59 (GMT +8)