



# SUMMA2020

2nd International Conference on Control Systems,  
Mathematical Modeling, Automation and Energy Efficiency

Industrial and Commercial Power and Power Conversion Systems – Energy Systems  
and Power Systems Engineering

## **Comparative Analysis of Electric Drives Control Systems Applied to Two-Phase Induction Motors**

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# Introduction

The purpose of the research: the conducting of a comprehensive analysis of the most known concepts of control systems for two-phase induction motors, such as:

- Direct start;
- Scalar control systems for one phase control and two phases control;
- Systems with continuous and discontinuous space vector pulse width modulation;
- System with relay current regulators.

Research object – model of asymmetrical two-phase induction motor from Matlab Simulink library, its parameters are

Nominal power, voltage, and frequency [ Pn(VA), Vn(Vrms), f(HZ) ]

[ .25\*746 110 60 ]

Main winding stator [ Rs(ohm), Lls(H) ]

[2.02 7.4e-3]

Main winding rotor [ Rr'(ohm), Llr'(H) ]

[4.12 5.6e-3]

Main winding mutual inductance Lms(H)

0.1772

Auxiliary winding stator [ RS(ohm), LIS(H) ]

[2.02 7.4e-3]

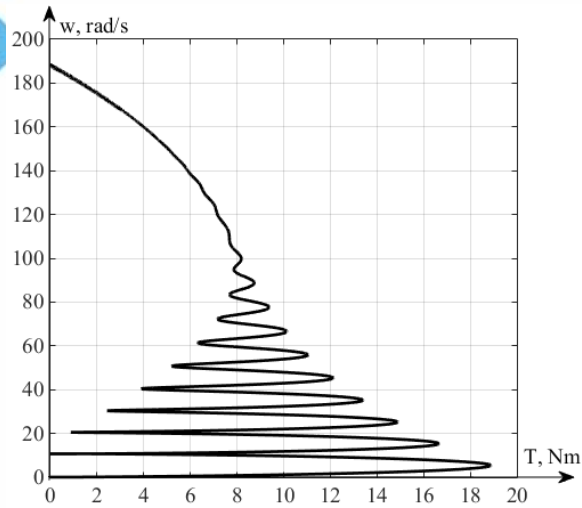
Inertia, friction factor, pole pairs, turn ratio(aux/main) [J(kg.m^2), F(N.m.s), p, NS/NS]

[0.0146 0 2 1]

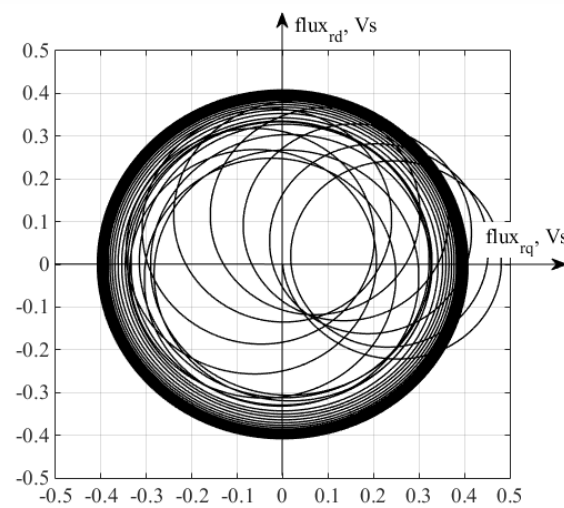
Comparable characteristics:

- mechanical characteristics;
- the shape of the rotor magnetic field;
- transient processes of phase currents;
- the number of switchings of the inverter switches per one second;
- Fast Furrier Analysis of phase currents (high harmonic content - THD).

# Description of the control algorithms: Direct start of TPIM

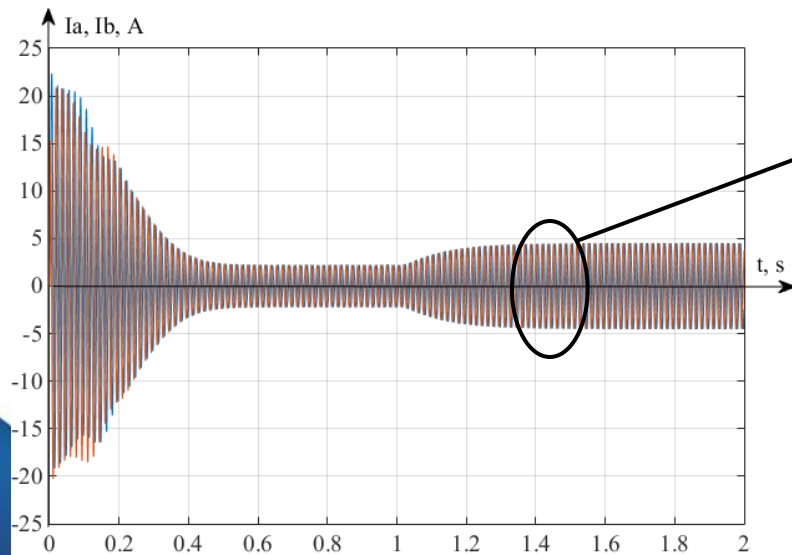


1. a)

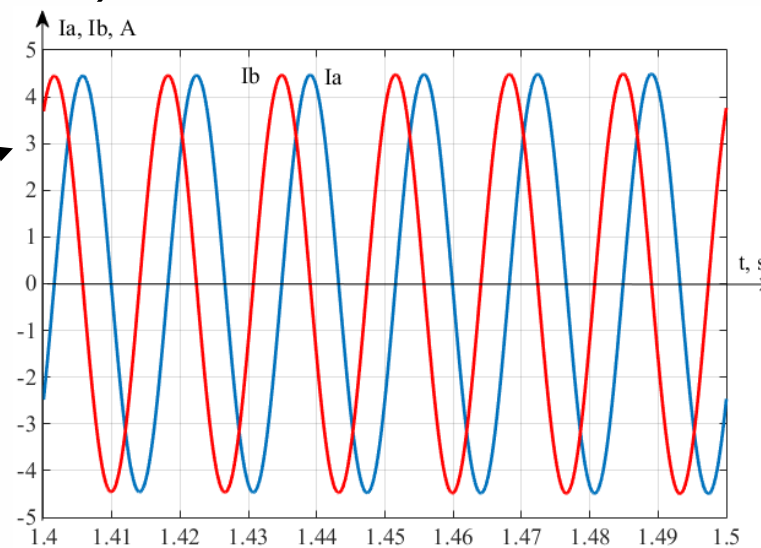


1. b)

- FFT analysis: THD are 0,31% and 0,28% for two phase currents.



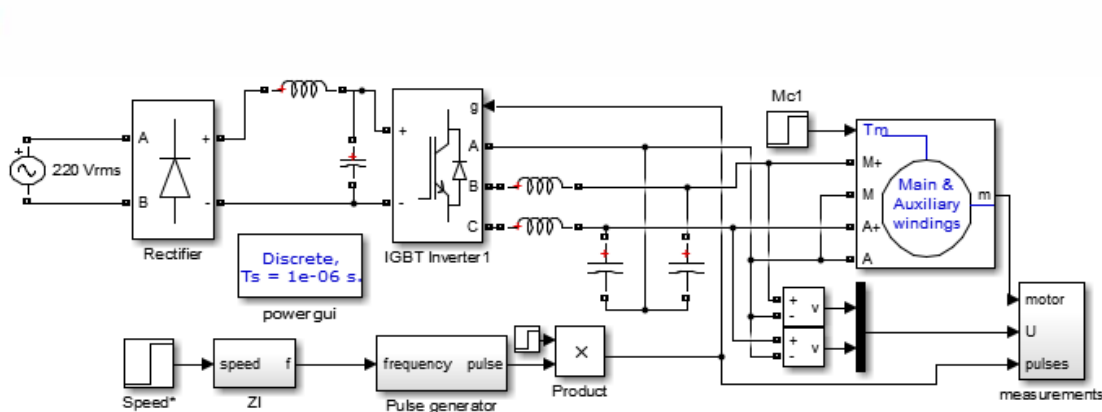
1. c)



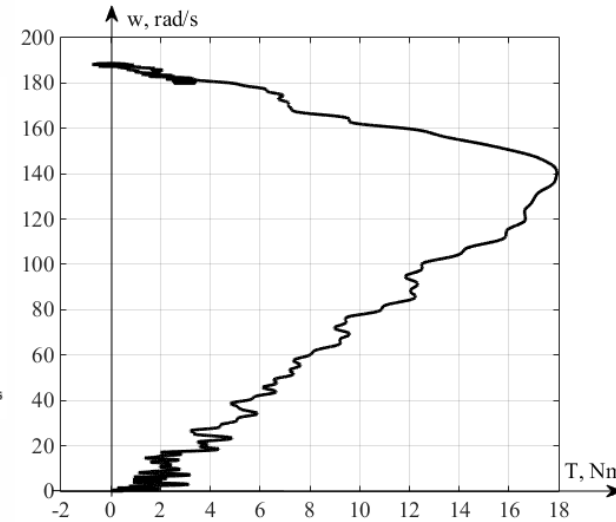
1 – Asymmetrical TPIM:

- a) Mechanical characteristic;
- b) Magnetic field;
- c) Phase currents.

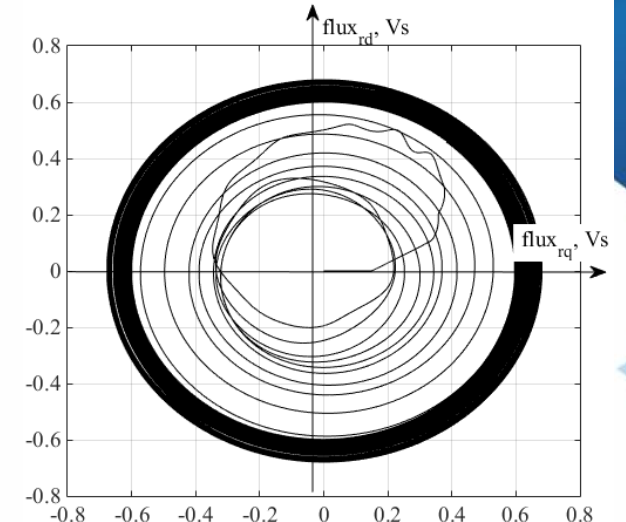
# Scalar control system of TPIM with two phases control



1 – Model of control system in Matlab Simulink

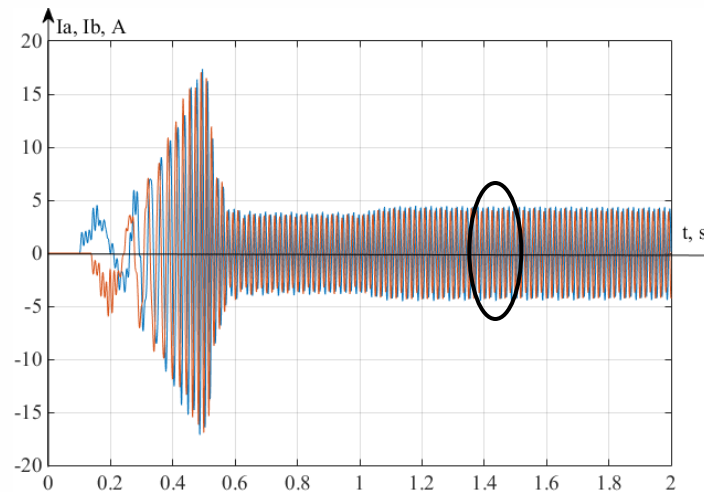


2. a)



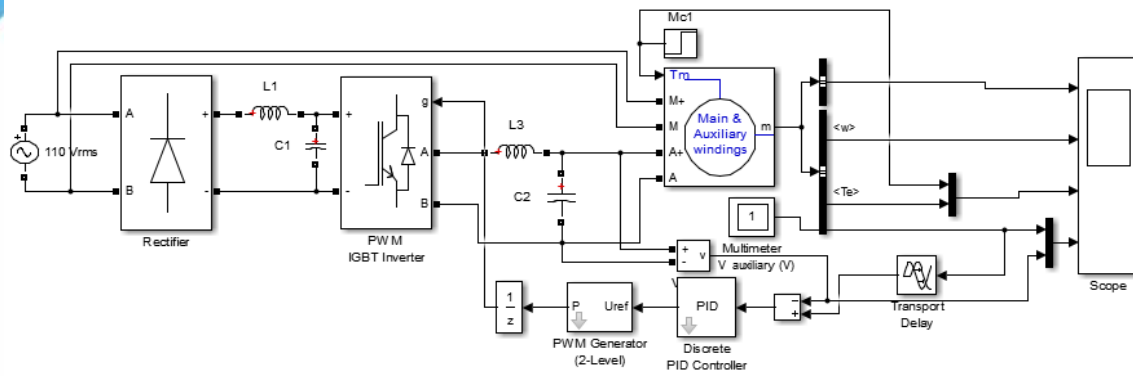
2. b)

- Based VSI frequency is 4 kHz;
- 3300 switch commutations in 1 second;
- FFT analysis: THD are 1,15% and 1,84% for two phase currents.

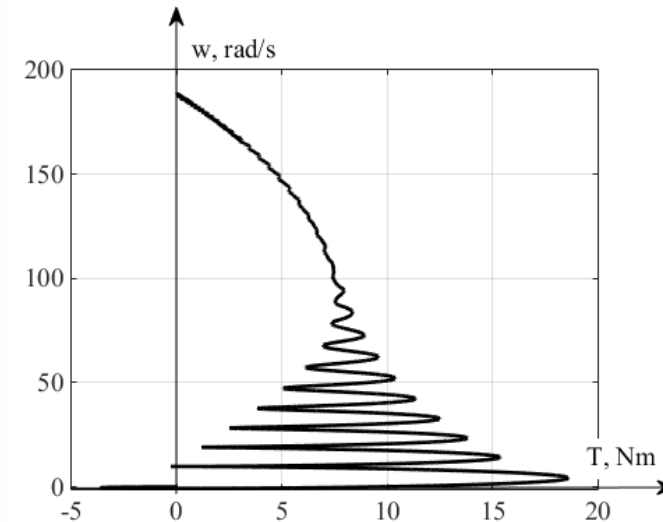


2. c)

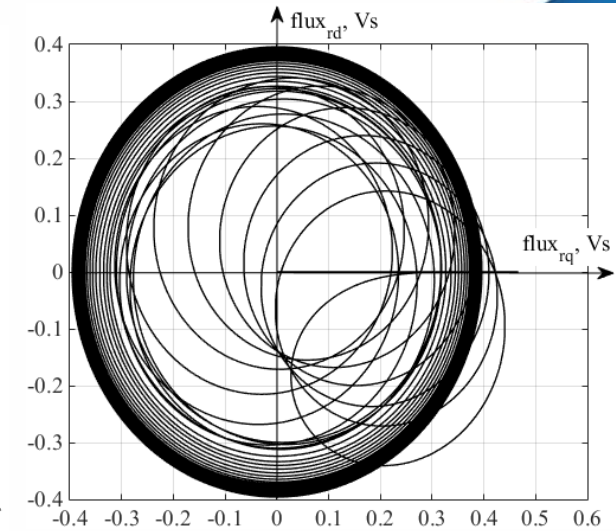
# Control system with TPIM one phase control



1 – Model of control system in Matlab Simulink

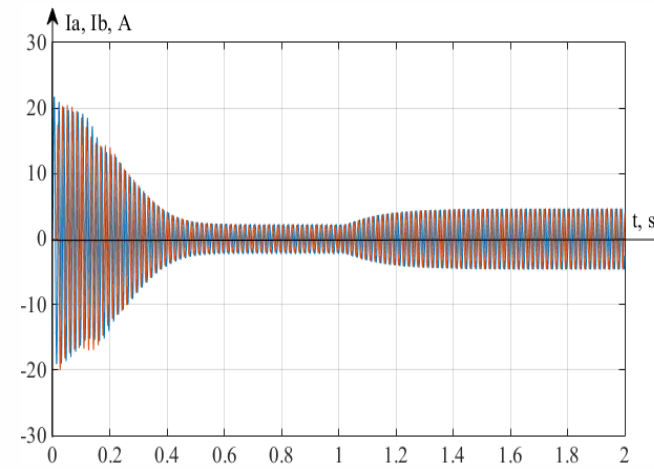


2. a)

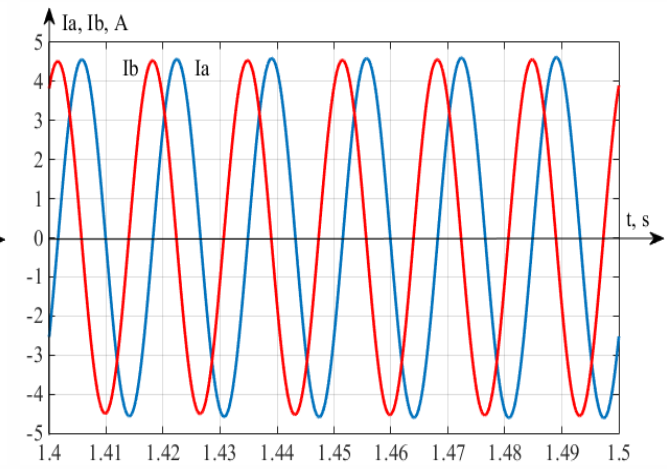


2. b)

- Based VSI frequency is 4 kHz;
- 1905 switch commutations in 1 second;
- FFT analysis: THD are 0,03% and 0,10% for two phase currents.



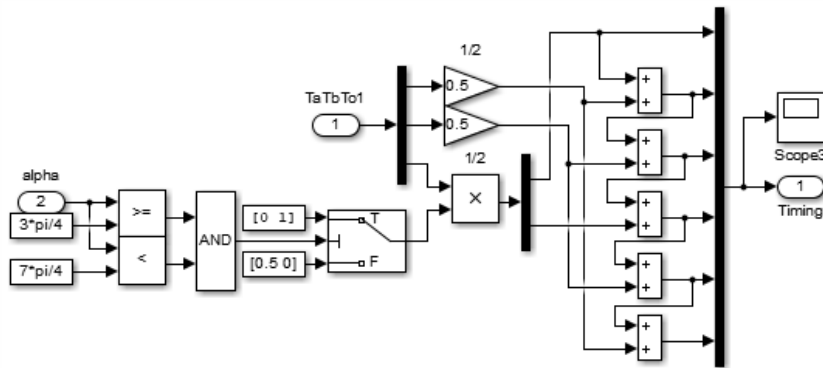
2. c)



A graph showing the currents  $I_a$  and  $I_b$  in Amperes (A) versus time  $t$  in seconds (s). The x-axis ranges from 2.4 to 2.5 s with major ticks every 0.02 s. The y-axis ranges from -20 to 20 A with major ticks every 10 A. The blue curve ( $I_a$ ) is a sinusoidal current with an amplitude of approximately 15 A and a period of 0.01 s. The red curve ( $I_b$ ) is a sinusoidal current with an amplitude of approximately 5 A and a period of 0.01 s, shifted by  $\pi$  relative to  $I_a$ .

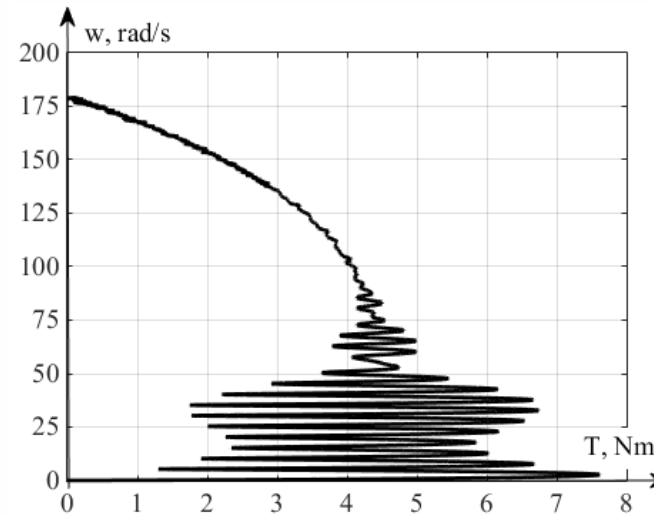
- November 11 – 13, 2020

# Control system with Hybrid SVPWM of TPIM

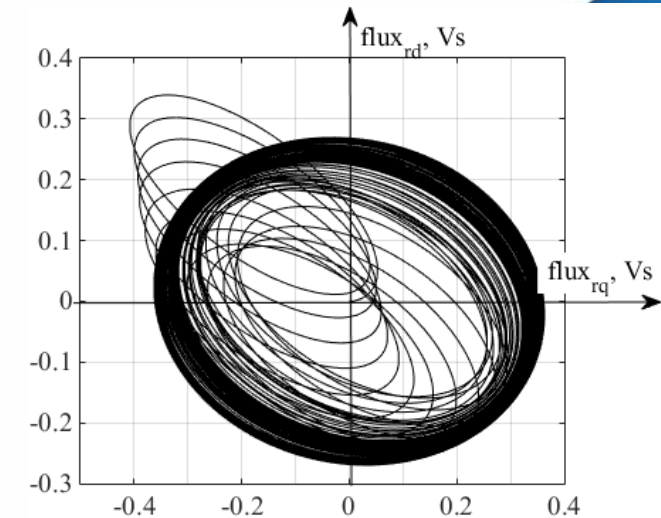


1 – Timing block for dividing vector space to spares of MinSVPWM and MaxSVPWM

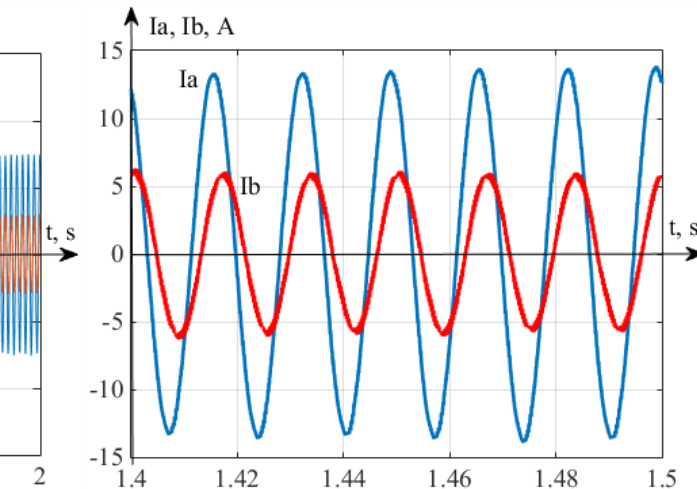
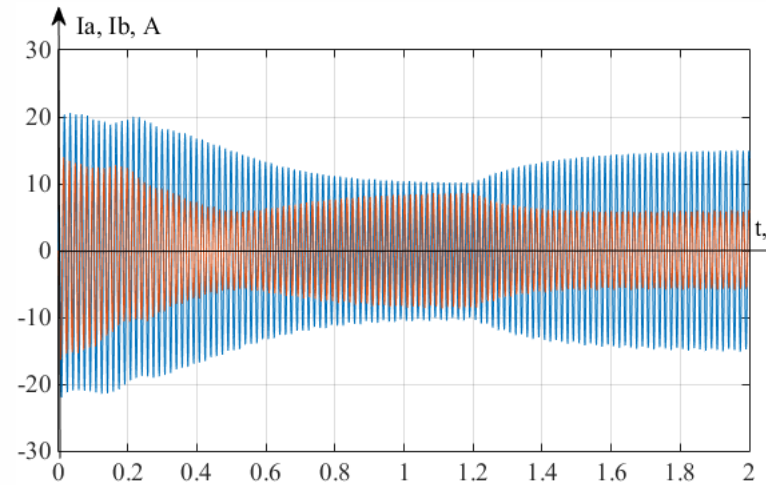
- Based VSI frequency is 4 kHz;
- 2770 switch commutations in 1 second in phase legs;
- 1920 switch commutations in 1 second in common leg;
- FFT analysis: THD are 1,35% and 3,37% for two phase currents.



2. a)

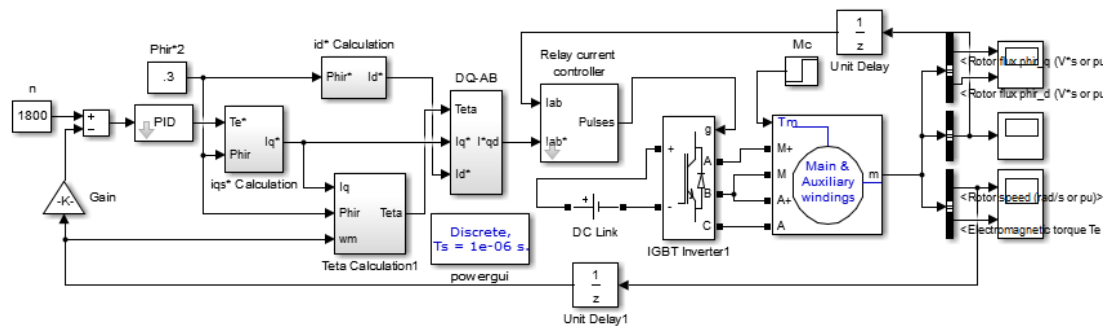


2. b)

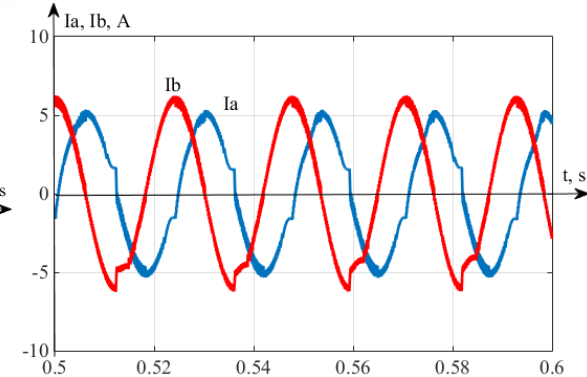
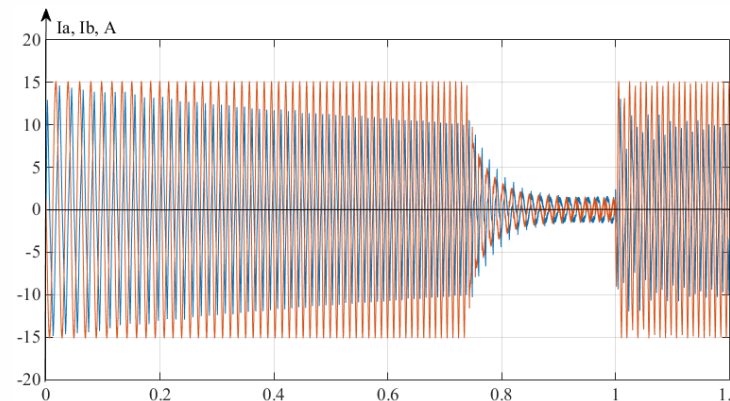
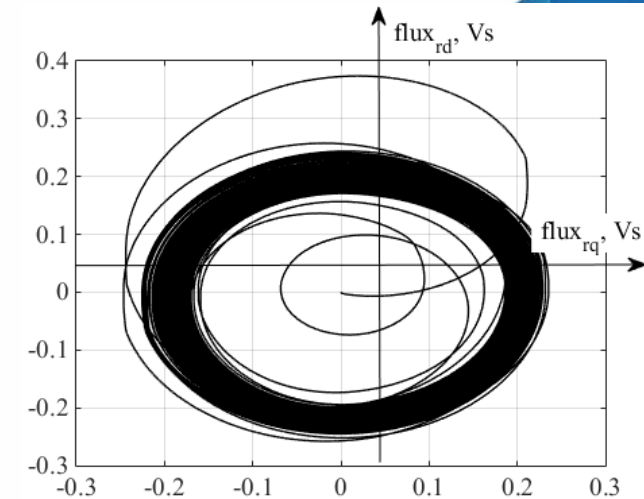
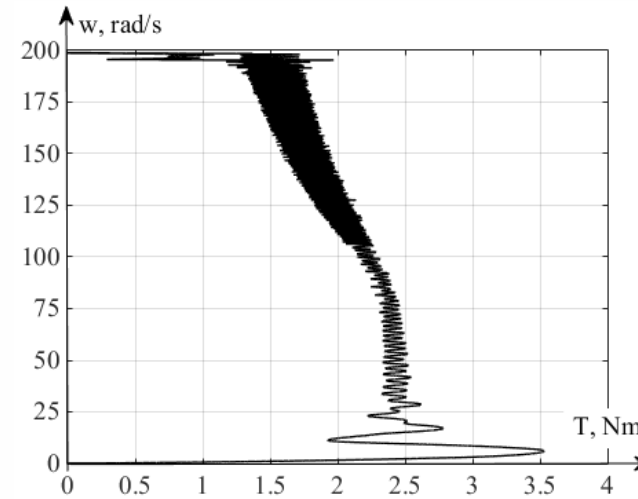


2. c)

# Control system with RCR of TPIM



- 5350 switch commutations in 1 second in phase legs and 400 switch commutations in 1 second in common leg during acceleration;
- 4700 switch commutations in 1 second in phase legs and 100 switch commutations in 1 second in common leg during work with increased load;
- FFT analysis: THD are 23,5% and 14,2% for two phase currents.



## The results of the research

| Type of TPIM control system                      | Scalar CS of two phases with carrier-based PWM | Scalar CS of one phase with carrier-based PWM                                                                | Continuous Space vector PWM             | Hybrid Discontinuous SVPWM                                                                                                   | CS with relay current regulators                                                                                    |
|--------------------------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Mechanical characteristic (max torque)           | Small torque ripples, 18Nm                     | Damped oscillations, 18Nm  | Damped oscillations, 7Nm                | Damped oscillations, 7,5Nm                                                                                                   | Small continuous ripples, 3,5Nm  |
| Shape of rotor magnetic field                    | Circle, radius 0,65                            | Circle, radius 0,4        | Ellipse, radiuses 0,35(q), 0,25 (d)     | Ellipse, radiuses 0,35(q), 0,25(d)                                                                                           | Circle, radius 0,22                                                                                                 |
| Phase currents transient process (max amplitude) | 0,6s, 17A                                      | 0,5s, 22A                                                                                                    | 1s, 20A                                 | 1s, 20A                                                                                                                      | 0,85s, 15A                       |
| Number of VSI switchings                         | 3300 for 6 switches                            | 1905 for 4 switches      | 3580 (4 switches) and 4000 (2 switches) | 2770 (4 switches) and 1920 (2 switches)  | 4700 (4 switches) and 100 (2 switches)                                                                              |
| High harmonic content of phase currents          | 1,15%, 1,84%                                   | 0,03%, 0,10%            | 1,65%, 4,10%                            | 1,35%, 3,37%                            | 23,5%, 14,2%                                                                                                        |

# Conclusion. Possible applications of two-phase electric drive systems



Control system with  
relay current  
regulators

Scalar control system  
of two phases with  
carrier-based PWM

Control system with  
space vector PWM



Scalar control system  
of one phase with  
carrier-based PWM



# Thank you for the attention!

**Oleg Kryukov, Stanimir Valtchev,  
Viktor Meshcheryakov, Aleksey Belousov**

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