

Układ sterowania filtrem aktywnym i dynamicznym stabilizatorem napięcia

Katedra Automatyki i Robotyki, AGH, Kraków, 2018-06-06.

Plan

Prointerface - zespół

Filtr aktywny – zasada pracy, schemat 3W oraz 4W

Architektura sterownika, czas rzeczywisty, generacja aplikacji

Regulator

Wyniki

Dynamiczny stabilizator napięcia - zasada pracy, schemat, wyniki

Katedry Energoelektroniki i Automatyki Systemów Przetwarzania Energii

prof. dr hab. inż. Z. Hanzelka, dr inż. K. Chmielowiec

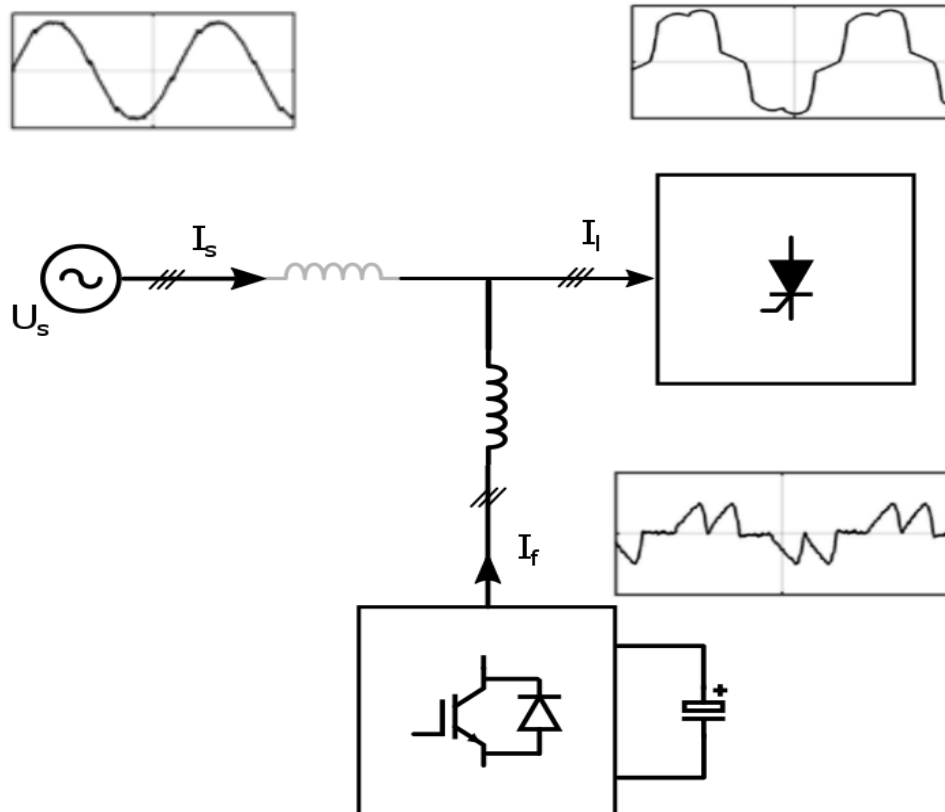
- dr inż. A. Dziadecki., inż. J. Skotniczny (energoelektronika)
- dr inż. A. Firlit (APF), dr Inż. K. Piątek (DVR)

Katedry Automatyki i Robotyki

- prof. dr hab. inż. W. Grega, dr inż. K. Kołek, dr inż. P. Piątek, dr inż. T. Dziwiński

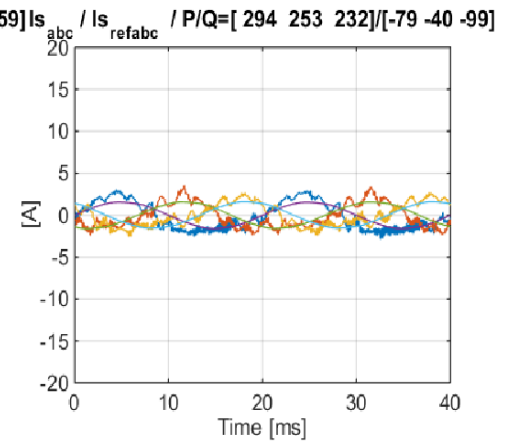
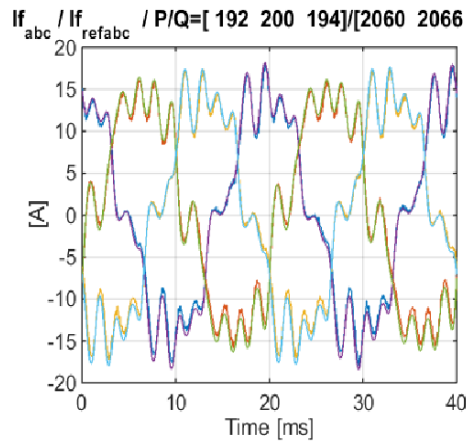
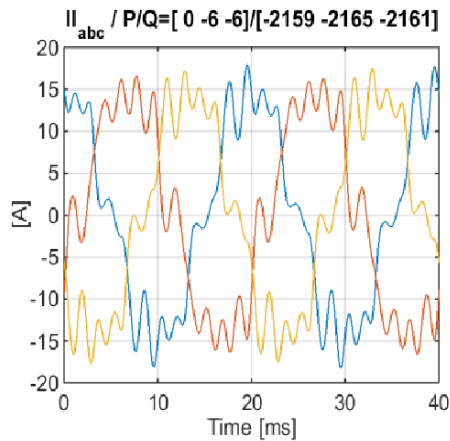
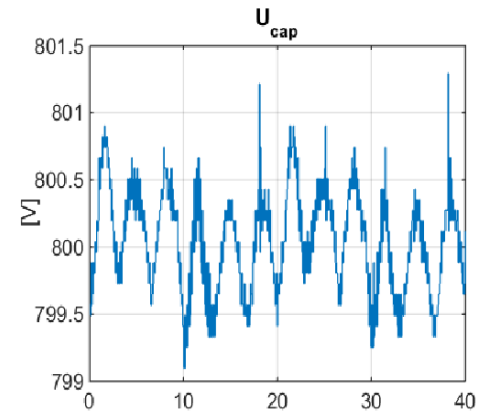
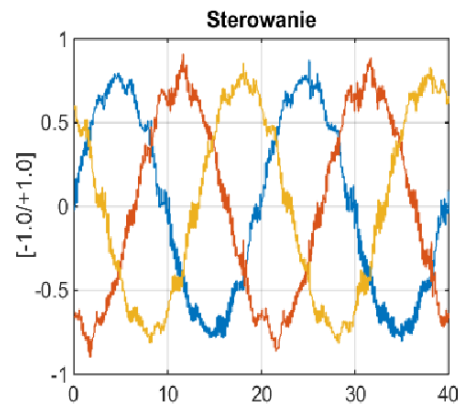
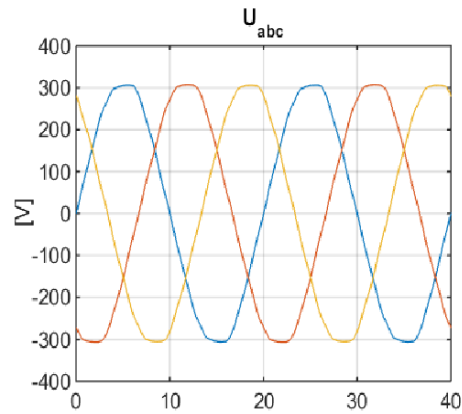
Elsta Elektronika Sp. z o.o. S.K.A., ul. Janińska 32, 32-020 Wieliczka

Filtr aktywny – zasada pracy, schemat 3W oraz 4W



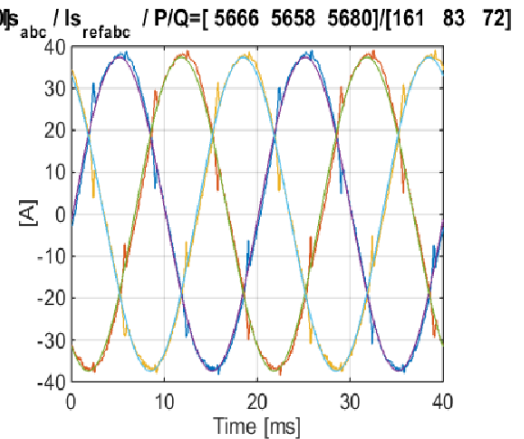
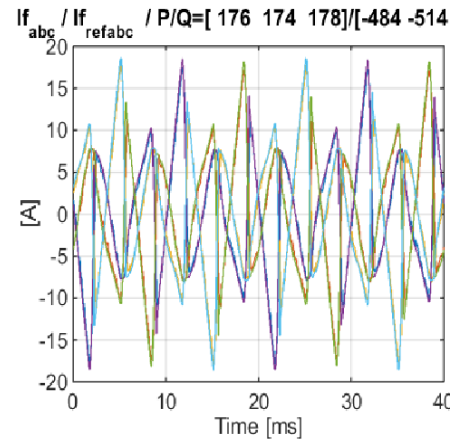
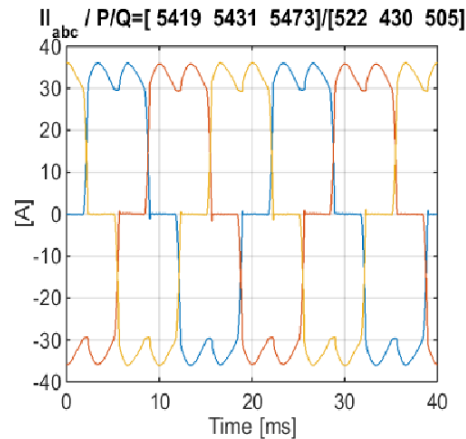
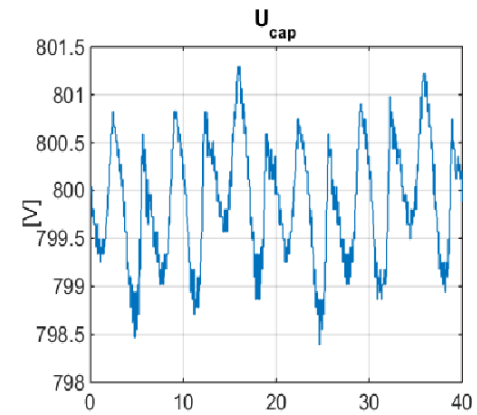
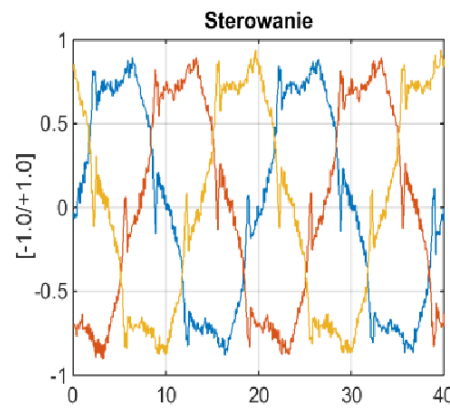
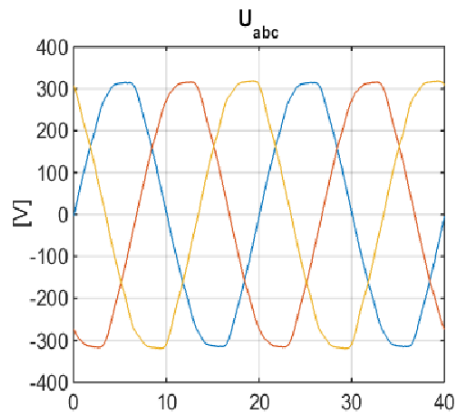
Filtr aktywny – zasada pracy, schemat 3W oraz 4W

Obciążenie: $3 \times 50\mu\text{F} + 0.8\text{mH}$ gwiazda



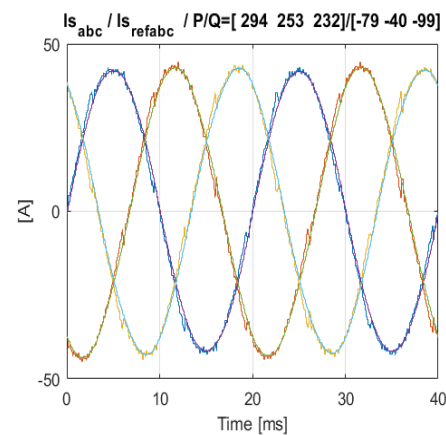
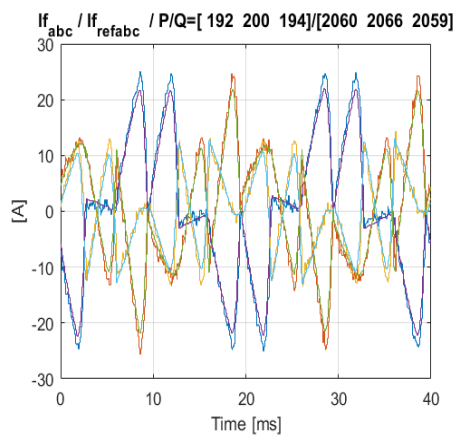
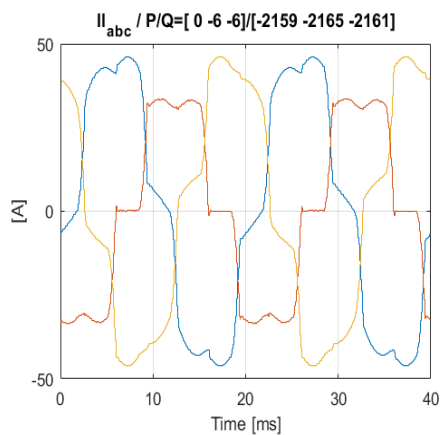
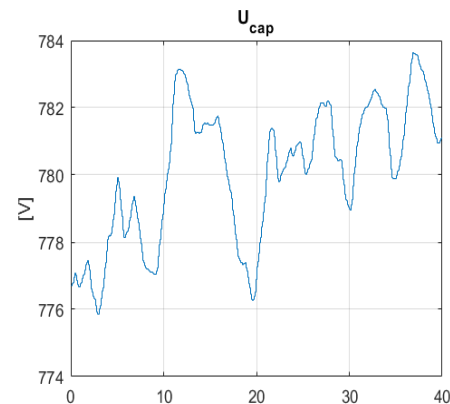
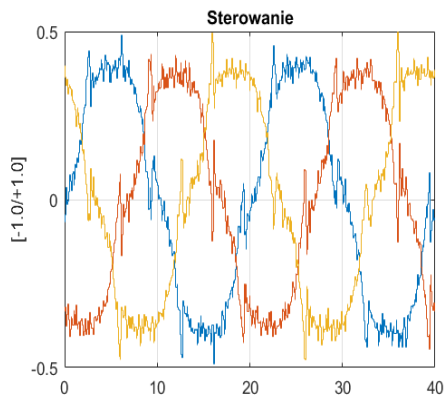
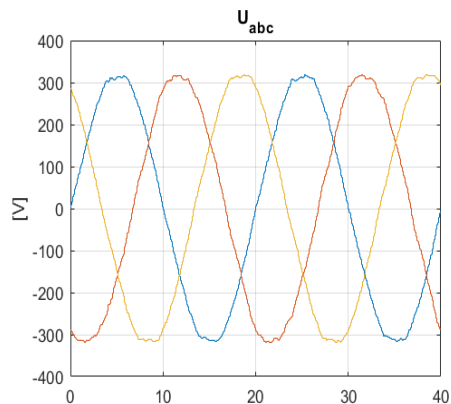
Filtr aktywny – zasada pracy, schemat 3W oraz 4W

$$THD = \frac{\sqrt{\sum_{k=2}^n I_k^2}}{I_1}, \quad THD_I = [27.9 \ 27.7 \ 28.3] \%, \quad THD_s = [5.3 \ 5.6 \ 5.3] \%$$

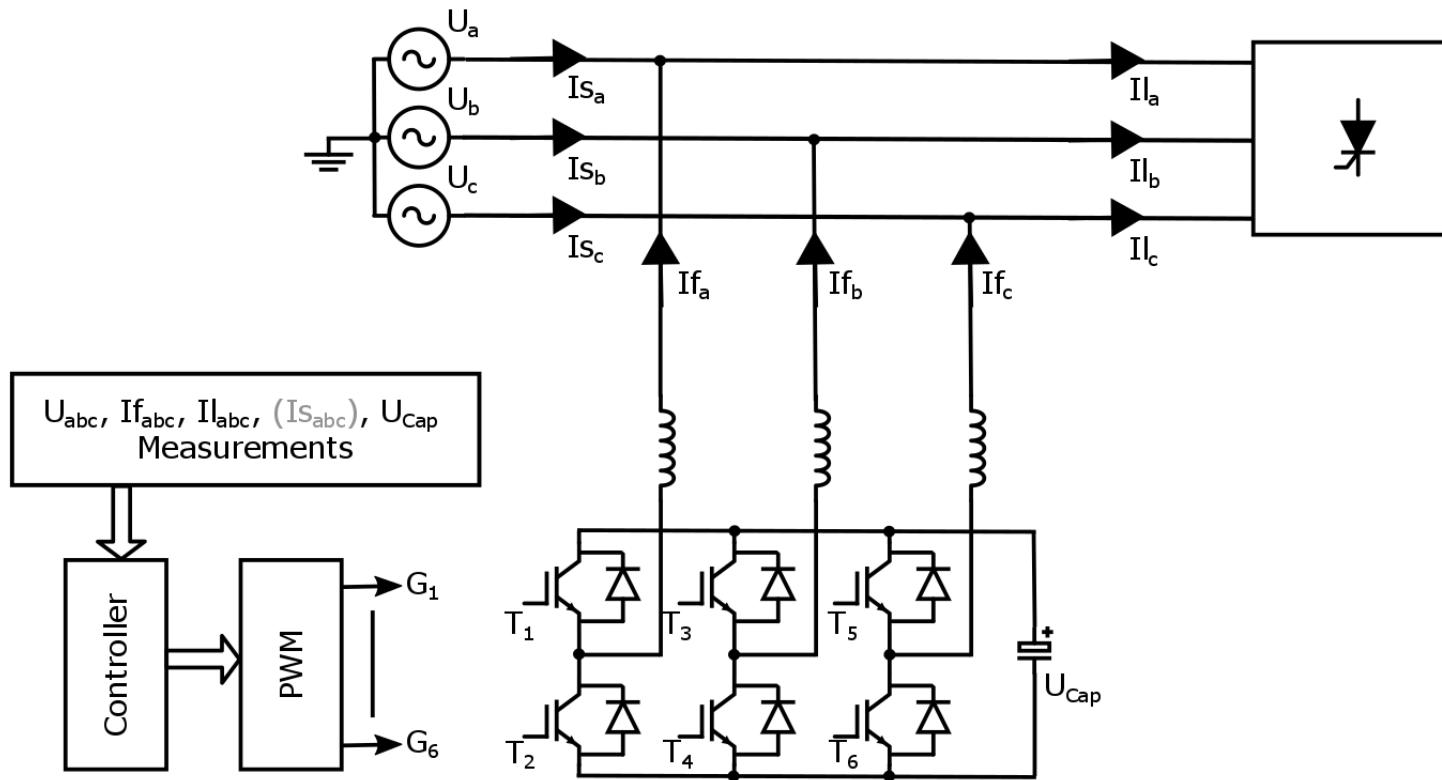


Filtr aktywny – zasada pracy, schemat 3W oraz 4W

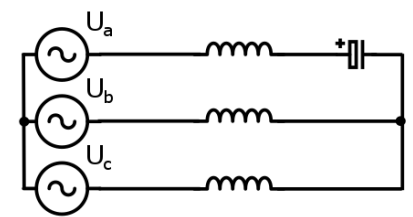
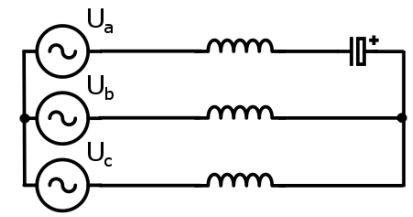
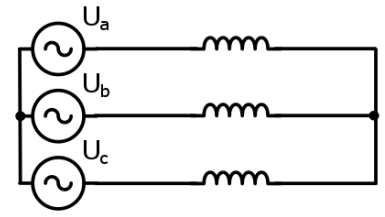
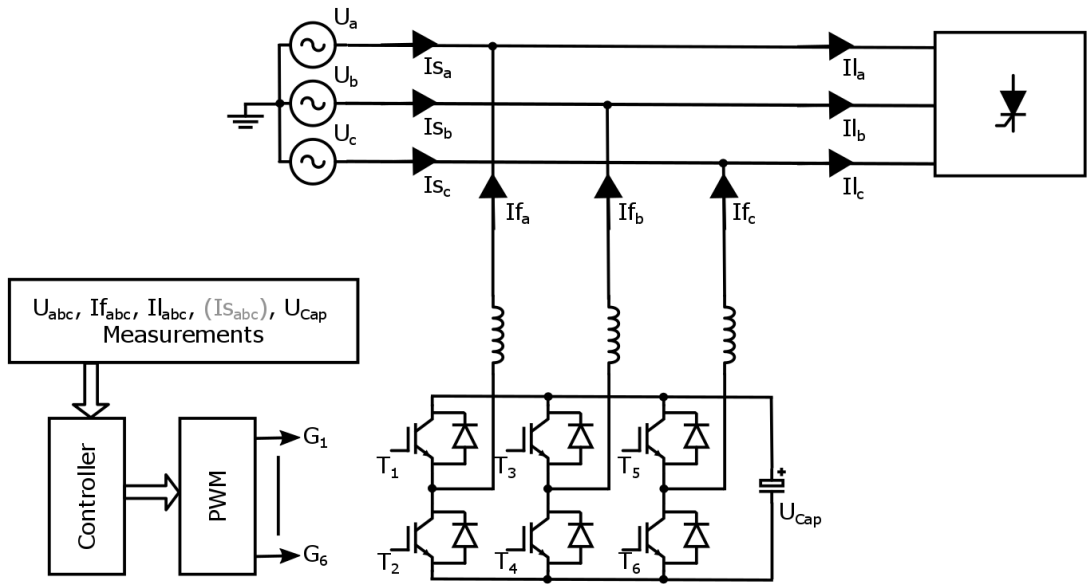
Niesymetria



Filtr aktywny – zasada pracy, schemat 3W oraz 4W



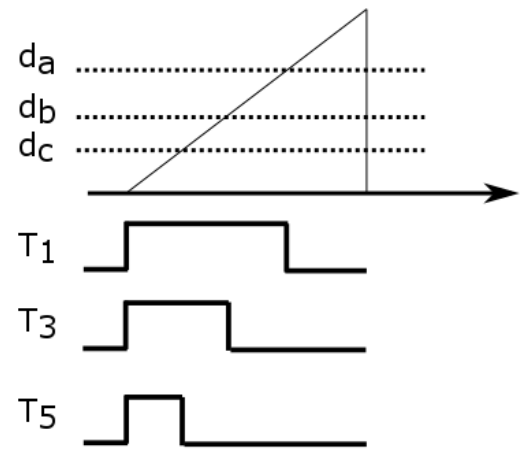
Filtr aktywny – zasada pracy, schemat 3W oraz 4W



$L = 2 \text{ mH}$

$f = 14.629 \text{ kHz}$

$T_0 = 68.36 \text{ } \mu\text{s}$

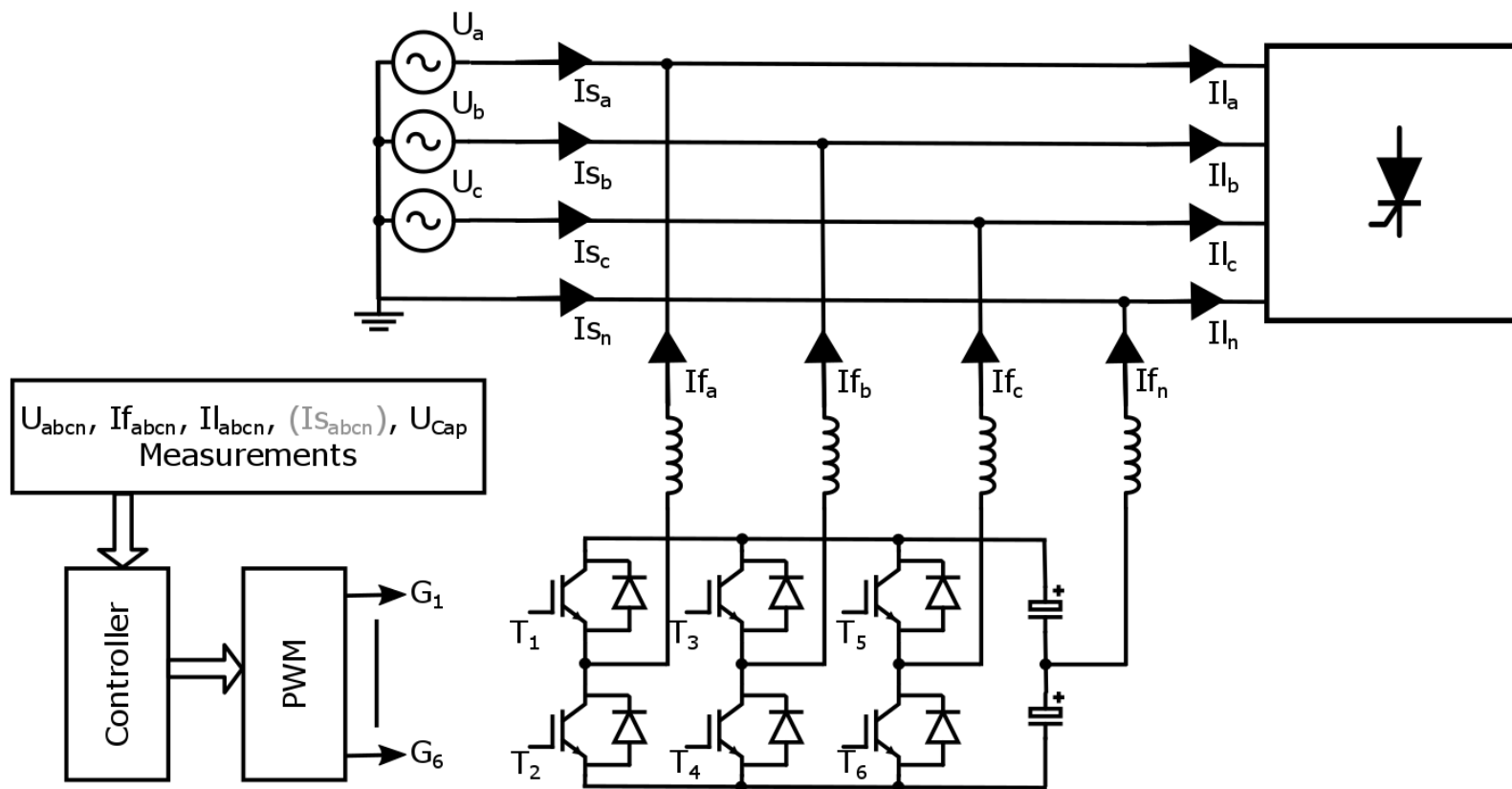


Filtr aktywny – zasada pracy, schemat 3W oraz 4W

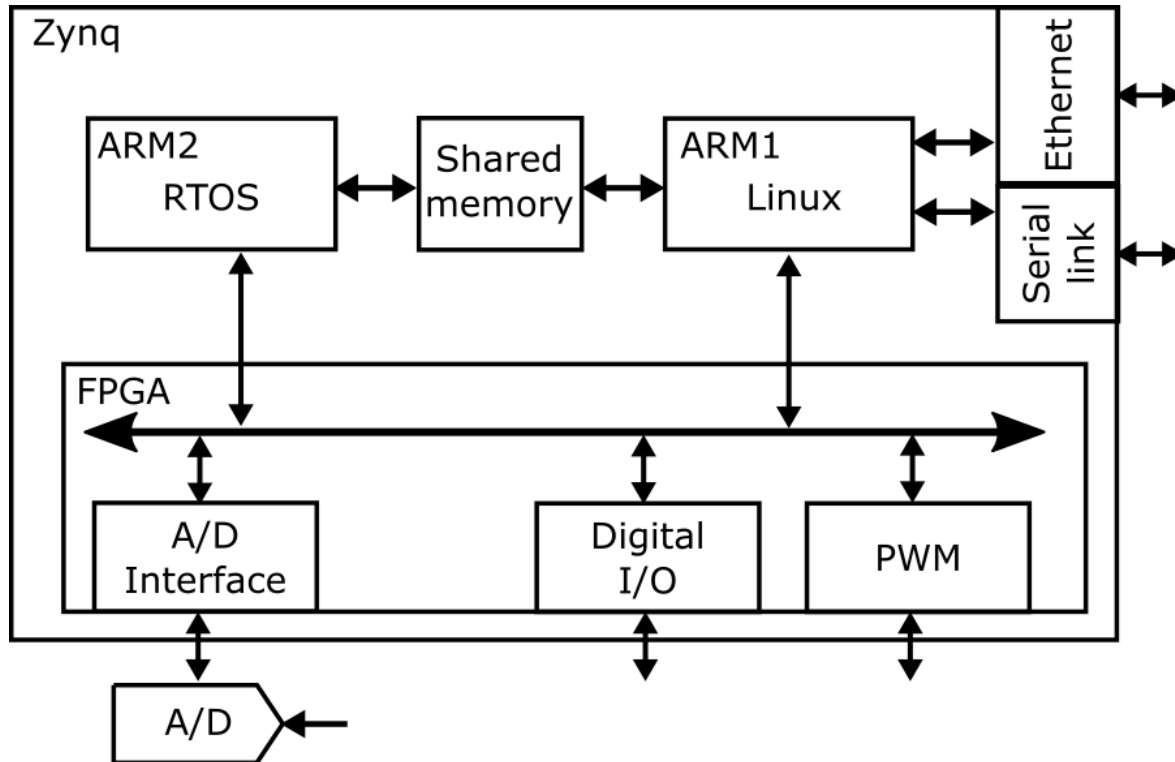
$$U_{Labc} = \begin{bmatrix} \frac{E_b}{3} - \frac{2E_a}{3} + \frac{E_c}{3} - \frac{U_{dc}(d_b - 2d_a + d_c)}{3} \\ \frac{E_a}{3} - \frac{2E_b}{3} + \frac{E_c}{3} - \frac{U_{dc}(d_a - 2d_b + d_c)}{3} \\ \frac{E_a}{3} + \frac{E_b}{3} - \frac{2E_c}{3} - \frac{U_{dc}(d_a + d_b - 2d_c)}{3} \end{bmatrix}$$

$$If_{abc}(t + T_0) = \begin{bmatrix} i_a(t + T_0) \\ i_b(t + T_0) \\ i_c(t + T_0) \end{bmatrix} = \begin{bmatrix} i_a(t) - \frac{T_0(\frac{2E_a}{3} - \frac{E_b}{3} - \frac{E_c}{3} + \frac{U_{dc}(d_b - 2d_a + d_c)}{3})}{L} \\ i_b(t) + \frac{T_0(\frac{E_a}{3} - \frac{2E_b}{3} + \frac{E_c}{3} - \frac{U_{dc}(d_a - 2d_b + d_c)}{3})}{L} \\ i_c(t) + \frac{T_0(\frac{E_a}{3} + \frac{E_b}{3} - \frac{2E_c}{3} - \frac{U_{dc}(d_a + d_b - 2d_c)}{3})}{L} \end{bmatrix}$$

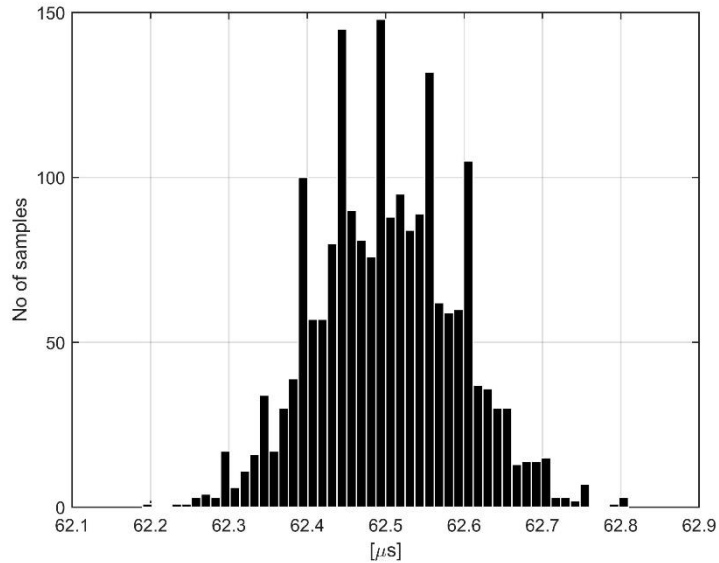
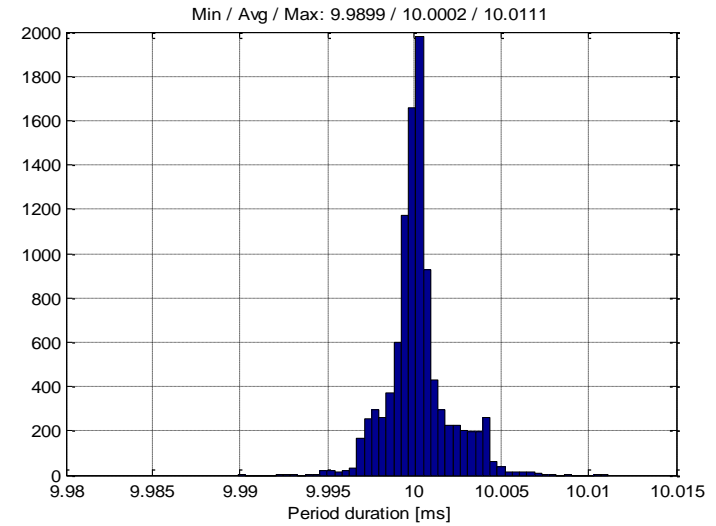
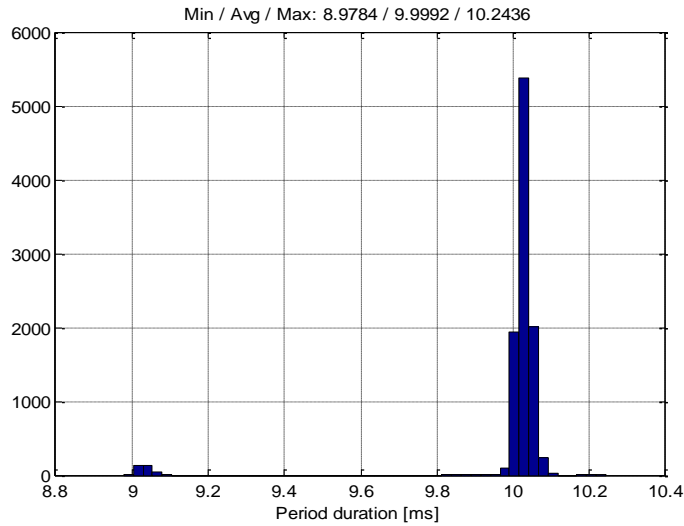
Filtr aktywny – zasada pracy, schemat 3W oraz 4W



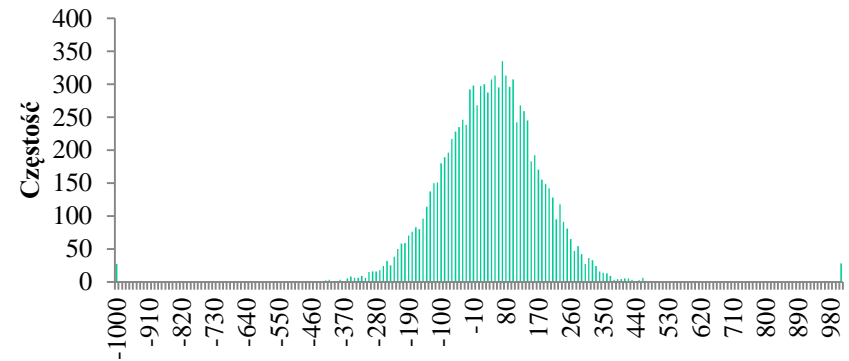
Architektura sterownika, czas rzeczywisty, generacja aplikacji



Architektura sterownika, czas rzeczywisty, generacja aplikacji

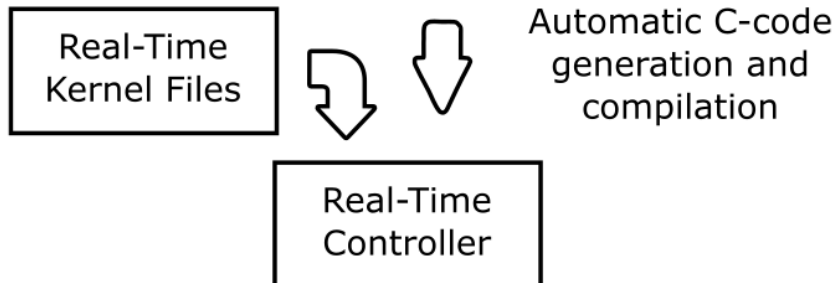
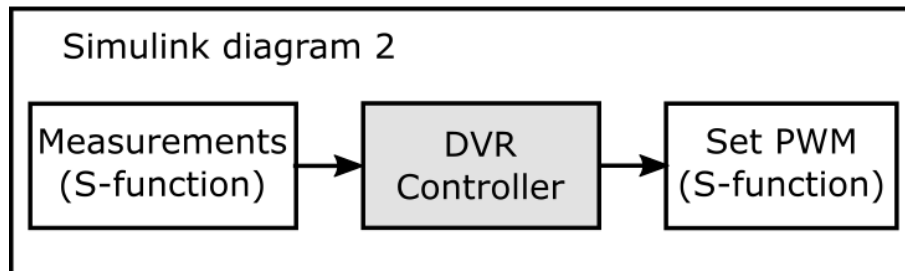
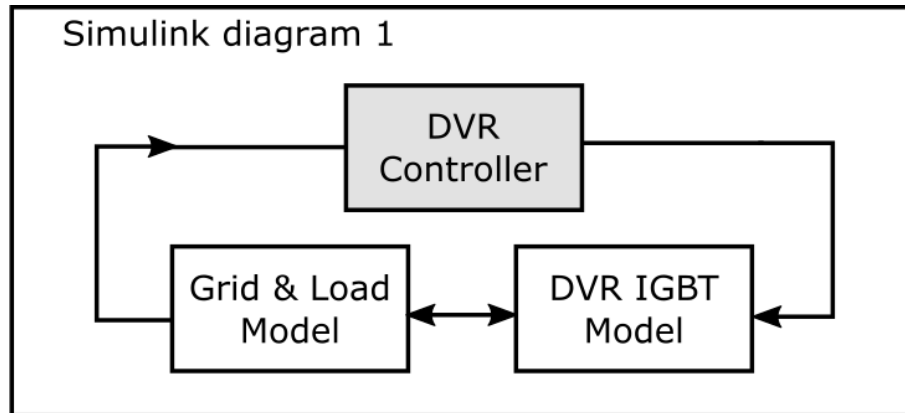


QNX - okres 50 μ s



Odchylenie od okresu [ns]

Architektura sterownika, czas rzeczywisty, generacja aplikacji



Architektura sterownika, czas rzeczywisty, generacja aplikacji

The screenshot shows a software interface for a PicoZed target. The main window title is "APF100 - PicoZed target - 4W". The interface includes a Model Browser on the left, a search icon, and several logos (ELSTA and AGH). A pink box displays timing information: $T_p = 68.36\mu s / 14629\text{Hz}$ and $T_{SW} = 68.36\mu s / 14629\text{Hz}$, with a "Show samplings" button below it. A yellow sticky note icon labeled "notes" is also present. On the right, there are three buttons: "SetParams_Elsta_4W_15", "uZDashboard", and "open uZHostIP.m", along with a "Scope usage" button and a laptop icon. The main workspace contains six red-outlined boxes labeled "A/D converters", "Init", "Aux", "Measurements", and "APF". The status bar at the bottom shows "Ready", "260%", and "ode1".

$$f(d_a, d_b, d_c) = (If_{abc}(t + T_0) - If_{refabc})^T (If_{abc}(t + T_0) - If_{refabc})$$

$$\min_{d_a, d_b, d_c} f(d_a, d_b, d_c)$$

$$If_{abc}(t + T_0) = \begin{bmatrix} i_a(t) - \frac{T_0 \left(\frac{2E_a}{3} - \frac{E_b}{3} - \frac{E_c}{3} + \frac{U_{dc}(d_b - 2d_a + d_c)}{3} \right)}{L} \\ i_b(t) + \frac{T_0 \left(\frac{E_a}{3} - \frac{2E_b}{3} + \frac{E_c}{3} - \frac{U_{dc}(d_a - 2d_b + d_c)}{3} \right)}{L} \\ i_c(t) + \frac{T_0 \left(\frac{E_a}{3} + \frac{E_b}{3} - \frac{2E_c}{3} - \frac{U_{dc}(d_a + d_b - 2d_c)}{3} \right)}{L} \end{bmatrix}$$

$$g_1 = d_a - 1 \leq 0, \quad g_2 = -d_a \leq 0$$

$$g_3 = d_b - 1 \leq 0, \quad g_4 = -d_b \leq 0$$

$$g_5 = d_c - 1 \leq 0, \quad g_6 = -d_c \leq 0$$

Warunki KT

$$\frac{\partial f}{\partial d_i} + \sum_{j=1}^6 \mu_j \frac{\partial g_j}{\partial d_i} = 0, \quad i = a, b, c$$

$$\mu_j g_j = 0, \quad j = 1, \dots, 6$$

Regulator

1	$\frac{1}{T_0 U_{dc}}$	$\frac{1}{T_0 U_{dc}}$
0	$\frac{Li_a - Li_b - Lid_a + Lid_b - E_a T_0 + E_b T_0}{T_0 U_{dc}}$	$\frac{Li_a - Li_c - Lid_a + Lid_c - E_a T_0 + E_c T_0}{T_0 U_{dc}}$
$-\frac{Li_a - Li_b - Lid_a + Lid_b - E_a T_0 + E_b T_0}{T_0 U_{dc}}$	0	$\frac{Li_b - Li_c - Lid_b + Lid_c - E_b T_0 + E_c T_0}{T_0 U_{dc}}$
$-\frac{Li_a - Li_c - Lid_a + Lid_c - E_a T_0 + E_c T_0}{T_0 U_{dc}}$	$-\frac{Li_b - Li_c - Lid_b + Lid_c - E_b T_0 + E_c T_0}{T_0 U_{dc}}$	0
1	$\frac{T_0 U_{dc} + Li_a - Li_b - Lid_a + Lid_b - E_a T_0 + E_b T_0}{T_0 U_{dc}}$	$\frac{T_0 U_{dc} + Li_a - Li_c - Lid_a + Lid_c - E_a T_0 + E_c T_0}{T_0 U_{dc}}$
$\frac{T_0 U_{dc} - Li_a + Li_b + Lid_a - Lid_b + E_a T_0 - E_b T_0}{T_0 U_{dc}}$	$\frac{T_0 U_{dc} + Li_a - Li_b - Lid_a + Lid_b - E_a T_0 + E_b T_0}{T_0 U_{dc}}$	$\frac{T_0 U_{dc} + Li_b - Li_c - Lid_b + Lid_c - E_b T_0 + E_c T_0}{T_0 U_{dc}}$
$\frac{T_0 U_{dc} - Li_a + Li_c + Lid_a - Lid_c + E_a T_0 - E_c T_0}{T_0 U_{dc}}$	1	$\frac{T_0 U_{dc} + Li_b - Li_c - Lid_b + Lid_c - E_b T_0 + E_c T_0}{T_0 U_{dc}}$
0	$\frac{T_0 U_{dc} - Li_b + Li_c + Lid_b - Lid_c + E_b T_0 - E_c T_0}{T_0 U_{dc}}$	1
0	0	$-\frac{2Li_c - Li_b - Li_a + Lid_a + Lid_b - 2Lid_c + E_a T_0 + E_b T_0 - 2E_c T_0}{2T_0 U_{dc}}$
$-\frac{2Li_a - Li_b - Li_c - 2Lid_a + Lid_b + Lid_c - 2E_a T_0 + E_b T_0 + E_c T_0}{2T_0 U_{dc}}$	$-\frac{2Li_b - Li_a - Li_c + Lid_a - 2Lid_b + Lid_c + E_a T_0 - 2E_b T_0 + E_c T_0}{2T_0 U_{dc}}$	0
1	0	0
1	0	0
0	1	0
1	0	1
0	0	1
0	1	1
1	1	$\frac{2T_0 U_{dc} + Li_a + Li_b - 2Li_c - Lid_a - Lid_b + 2Lid_c - E_a T_0 - E_b T_0 + 2E_c T_0}{2T_0 U_{dc}}$
1	$\frac{2T_0 U_{dc} + Li_a - 2Li_b + Li_c - Lid_a + 2Lid_b - Lid_c - E_a T_0 + 2E_b T_0 - E_c T_0}{2T_0 U_{dc}}$	1
$\frac{2T_0 U_{dc} - 2Li_a + Li_b + Li_c + 2Lid_a - Lid_b - Lid_c + 2E_a T_0 - E_b T_0 - E_c T_0}{2T_0 U_{dc}}$	1	1
$\frac{Li_c - Li_a + Lid_a - Lid_c + E_a T_0 - E_c T_0 + T_0 U_{dc} x}{T_0 U_{dc}}$	$\frac{Li_c - Li_b + Lid_b - Lid_c + E_b T_0 - E_c T_0 + T_0 U_{dc} x}{T_0 U_{dc}}$	x
1	0	$\frac{T_0 U_{dc} + Li_a + Li_b - 2Li_c - Lid_a - Lid_b + 2Lid_c - E_a T_0 - E_b T_0 + 2E_c T_0}{2T_0 U_{dc}}$
0	1	$\frac{T_0 U_{dc} + Li_a + Li_b - 2Li_c - Lid_a - Lid_b + 2Lid_c - E_a T_0 - E_b T_0 + 2E_c T_0}{2T_0 U_{dc}}$
1	$\frac{T_0 U_{dc} + Li_a - 2Li_b + Li_c - Lid_a + 2Lid_b - Lid_c - E_a T_0 + 2E_b T_0 - E_c T_0}{2T_0 U_{dc}}$	$\frac{T_0 U_{dc} + Li_a + Li_b - 2Li_c - Lid_a - Lid_b + 2Lid_c - E_a T_0 - E_b T_0 + 2E_c T_0}{2T_0 U_{dc}}$
0	$\frac{T_0 U_{dc} + Li_a - 2Li_b + Li_c - Lid_a + 2Lid_b - Lid_c - E_a T_0 + 2E_b T_0 - E_c T_0}{2T_0 U_{dc}}$	0
$\frac{T_0 U_{dc} - 2Li_a + Li_b + Li_c + 2Lid_a - Lid_b - Lid_c + 2E_a T_0 - E_b T_0 - E_c T_0}{2T_0 U_{dc}}$	1	1
$\frac{T_0 U_{dc} - 2Li_a + Li_b + Li_c + 2Lid_a - Lid_b - Lid_c + 2E_a T_0 - E_b T_0 - E_c T_0}{2T_0 U_{dc}}$	0	0
0	0	0

$$f(d_a, d_b, d_c) = (I_{fabc}(t + T_0) - I_{refabc})^T (I_{fabc}(t + T_0) - I_{refabc})$$

$$\min_{d_a, d_b} f(d_a, d_b), \quad d_c = 0$$

$$I_{fabc}(t + T_0) = \begin{bmatrix} i_a(t) - \frac{T_0 \left(\frac{2E_a}{3} - \frac{E_b}{3} - \frac{E_c}{3} + \frac{U_{dc}(d_b - 2d_a)}{3} \right)}{L} \\ i_b(t) + \frac{T_0 \left(\frac{E_a}{3} - \frac{2E_b}{3} + \frac{E_c}{3} - \frac{U_{dc}(d_a - 2d_b)}{3} \right)}{L} \\ i_c(t) + \frac{T_0 \left(\frac{E_a}{3} + \frac{E_b}{3} - \frac{2E_c}{3} - \frac{U_{dc}(d_a + d_b)}{3} \right)}{L} \end{bmatrix}$$

$$g_1 = d_a - 1 \leq 0, \quad g_2 = -d_a \leq 0$$

$$g_3 = d_b - 1 \leq 0, \quad g_4 = -d_b \leq 0$$

$$[d_a d_b] = \begin{pmatrix} -\frac{Li_a - Li_c - Lid_a + Lid_c - E_a T_0 + E_c T_0}{T_0 U_{dc}} & -\frac{Li_b - Li_c - Lid_b + Lid_c - E_b T_0 + E_c T_0}{T_0 U_{dc}} \\ 1 & \frac{T_0 U_{dc} + Li_a - 2Li_b + Li_c - Lid_a + 2Lid_b - Lid_c - E_a T_0 + 2E_b T_0 - E_c T_0}{2T_0 U_{dc}} \\ \frac{T_0 U_{dc} - 2Li_a + Li_b + Li_c + 2Lid_a - Lid_b - Lid_c + 2E_a T_0 - E_b T_0 - E_c T_0}{2T_0 U_{dc}} & 1 \\ 0 & -\frac{2Li_b - Li_a - Li_c + Lid_a - 2Lid_b + Lid_c + E_a T_0 - 2E_b T_0 + E_c T_0}{2T_0 U_{dc}} \\ -\frac{2Li_a - Li_b - Li_c - 2Lid_a + Lid_b + Lid_c - 2E_a T_0 + E_b T_0 + E_c T_0}{2T_0 U_{dc}} & 0 \\ 1 & 1 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{pmatrix}$$

APF 4W

$$U_{Labc} = \begin{bmatrix} \frac{E_b}{4} - \frac{3E_a}{4} + \frac{E_c}{4} + \frac{3U_a}{4} - \frac{U_b}{4} - \frac{U_c}{4} \\ \frac{E_a}{4} - \frac{3E_b}{4} + \frac{E_c}{4} - \frac{U_a}{4} + \frac{3U_b}{4} - \frac{U_c}{4} \\ \frac{E_a}{4} + \frac{E_b}{4} - \frac{3E_c}{4} - \frac{U_a}{4} - \frac{U_b}{4} + \frac{3U_c}{4} \end{bmatrix}$$

$$\begin{bmatrix} i_a(t + T_0) \\ i_b(t + T_0) \\ i_c(t + T_0) \end{bmatrix} = \begin{bmatrix} i_a(t) - \frac{T_0(\frac{3E_a}{4} - \frac{E_b}{4} - \frac{E_c}{4} - \frac{3U_a}{4} + \frac{U_b}{4} + \frac{U_c}{4})}{L} \\ i_b(t) + \frac{T_0(\frac{E_a}{4} - \frac{3E_b}{4} + \frac{E_c}{4} - \frac{U_a}{4} + \frac{3U_b}{4} - \frac{U_c}{4})}{L} \\ i_c(t) + \frac{T_0(\frac{E_a}{4} + \frac{E_b}{4} - \frac{3E_c}{4} - \frac{U_a}{4} - \frac{U_b}{4} + \frac{3U_c}{4})}{L} \end{bmatrix}$$

APF 4W

$$\frac{2Lid_a - Li_b - Li_c - 2Li_a + Lid_b + Lid_c + E_a T_0}{T_0}$$

Udcmin

Udcmax

$$5T_0 Udcmin - 7Li_a + 4Li_b - Li_c + 7Lid_a - 4Lid_b + Lid_c + 6E_a T_0 - 5E_b T_0$$

$$5T_0 Udcmax - 7Li_a + 4Li_b - Li_c + 7Lid_a - 4Lid_b + Lid_c + 6E_a T_0 - 5E_b T_0$$

$$5T_0 Udcmin - 7Li_a - Li_b + 4Li_c + 7Lid_a + Lid_b - 4Lid_c + 6E_a T_0 - 5E_c T_0$$

$$5T_0 Udcmax - 7Li_a - Li_b + 4Li_c + 7Lid_a + Lid_b - 4Lid_c + 6E_a T_0 - 5E_c T_0$$

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

$$5T_0 Udcmin + 5T_0 Udcmax - 12Li_a + 4Li_b + 4Li_c + 12Lid_a - 4Lid_b - 4Lid_c + 11E_a T_0 - 5E_b T_0 - 5E_c T_0$$

$$5T_0 Udcmin + 5T_0 Udcmax - 12Li_a + 4Li_b + 4Li_c + 12Lid_a - 4Lid_b - 4Lid_c + 11E_a T_0 - 5E_b T_0 - 5E_c T_0$$

Udcmin

Udcmax

Udcmin

Udcmax

$$10T_0 Udcmin - 12Li_a + 4Li_b + 4Li_c + 12Lid_a - 4Lid_b - 4Lid_c + 11E_a T_0 - 5E_b T_0 - 5E_c T_0$$

$$10T_0 Udcmax - 12Li_a + 4Li_b + 4Li_c + 12Lid_a - 4Lid_b - 4Lid_c + 11E_a T_0 - 5E_b T_0 - 5E_c T_0$$

Udcmin

Udcmax

$$\frac{Lid_a - 2Li_b - Li_c - Li_a + 2Lid_b + Lid_c + E_b T_0}{T_0}$$

$$5T_0 Udcmin + 4Li_a - 7Li_b - Li_c - 4Lid_a + 7Lid_b + Lid_c - 5E_a T_0 + 6E_b T_0$$

$$5T_0 Udcmax + 4Li_a - 7Li_b - Li_c - 4Lid_a + 7Lid_b + Lid_c - 5E_a T_0 + 6E_b T_0$$

$$5T_0 Udcmin - Li_a - 7Li_b + 4Li_c + Lid_a + 7Lid_b - 4Lid_c + 6E_b T_0 - 5E_c T_0$$

$$5T_0 Udcmax - Li_a - 7Li_b + 4Li_c + Lid_a + 7Lid_b - 4Lid_c + 6E_b T_0 - 5E_c T_0$$

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

$$5T_0 Udcmin + 5T_0 Udcmax + 4Li_a - 12Li_b + 4Li_c - 4Lid_a + 12Lid_b - 4Lid_c - 5E_a T_0 + 11E_b T_0 - 5E_c T_0$$

$$5T_0 Udcmin + 5T_0 Udcmax + 4Li_a - 12Li_b + 4Li_c - 4Lid_a + 12Lid_b - 4Lid_c - 5E_a T_0 + 11E_b T_0 - 5E_c T_0$$

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

$$10T_0 Udcmin + 4Li_a - 12Li_b + 4Li_c - 4Lid_a + 12Lid_b - 4Lid_c - 5E_a T_0 + 11E_b T_0 - 5E_c T_0$$

$$10T_0 Udcmax + 4Li_a - 12Li_b + 4Li_c - 4Lid_a + 12Lid_b - 4Lid_c - 5E_a T_0 + 11E_b T_0 - 5E_c T_0$$

Udcmin

Udcmax

Udcmin

Udcmax

$$\frac{Lid_a - Li_b - 2Li_c - Li_a + Lid_b + 2Lid_c + E_c T_0}{T_0}$$

$$5T_0 Udcmin + 4Li_a - Li_b - 7Li_c - 4Lid_a + Lid_b + 7Lid_c - 5E_a T_0 + 6E_c T_0$$

$$5T_0 Udcmax + 4Li_a - Li_b - 7Li_c - 4Lid_a + Lid_b + 7Lid_c - 5E_a T_0 + 6E_c T_0$$

$$5T_0 Udcmin - Li_a + 4Li_b - 7Li_c + Lid_a - 4Lid_b + 7Lid_c - 5E_b T_0 + 6E_c T_0$$

$$5T_0 Udcmax - Li_a + 4Li_b - 7Li_c + Lid_a - 4Lid_b + 7Lid_c - 5E_b T_0 + 6E_c T_0$$

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

$$5T_0 Udcmin + 5T_0 Udcmax + 4Li_a + 4Li_b - 12Li_c - 4Lid_a - 4Lid_b + 12Lid_c - 5E_a T_0 - 5E_b T_0 + 11E_c T_0$$

$$5T_0 Udcmin + 5T_0 Udcmax + 4Li_a + 4Li_b - 12Li_c - 4Lid_a - 4Lid_b + 12Lid_c - 5E_a T_0 - 5E_b T_0 + 11E_c T_0$$

Udcmin

Udcmax

Udcmin

Udcmax

Udcmin

Udcmax

$$10T_0 Udcmin + 4Li_a + 4Li_b - 12Li_c - 4Lid_a - 4Lid_b + 12Lid_c - 5E_a T_0 - 5E_b T_0 + 11E_c T_0$$

$$10T_0 Udcmax + 4Li_a + 4Li_b - 12Li_c - 4Lid_a - 4Lid_b + 12Lid_c - 5E_a T_0 - 5E_b T_0 + 11E_c T_0$$

Udcmin

Udcmax

Udcmin

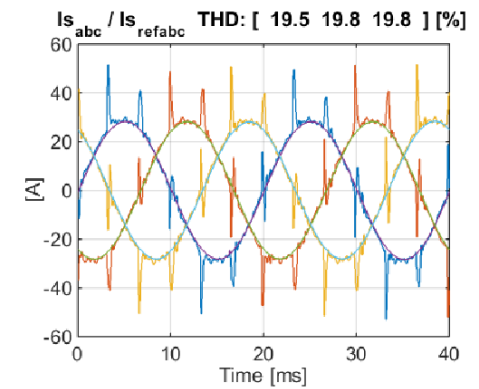
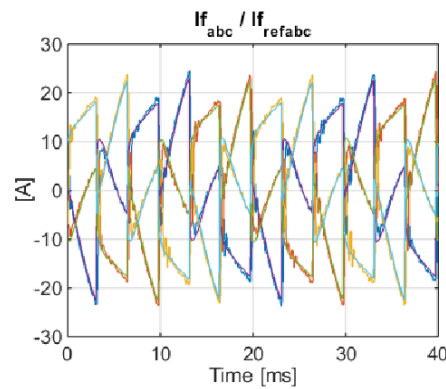
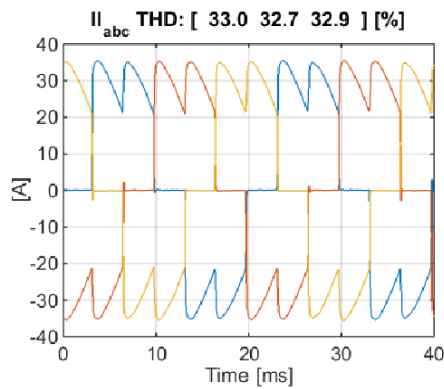
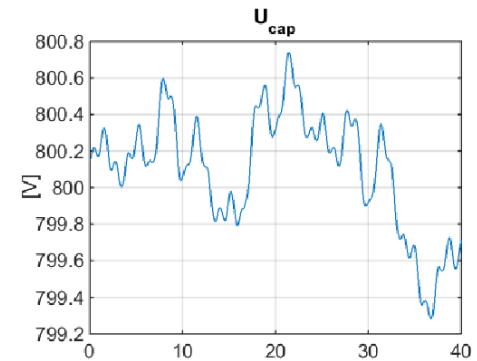
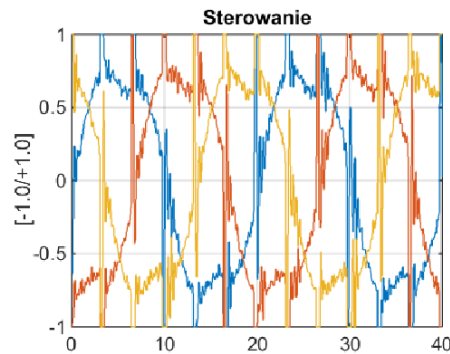
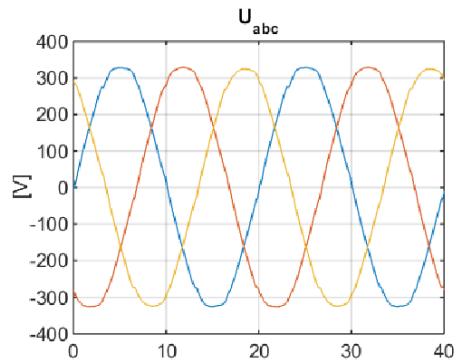
Udcmax

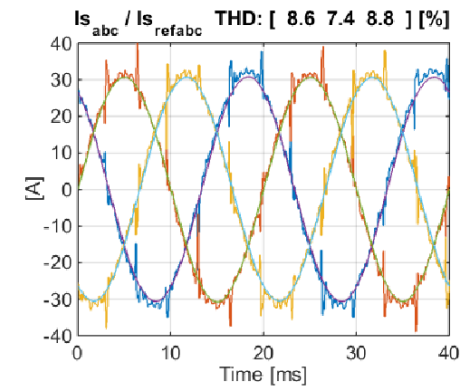
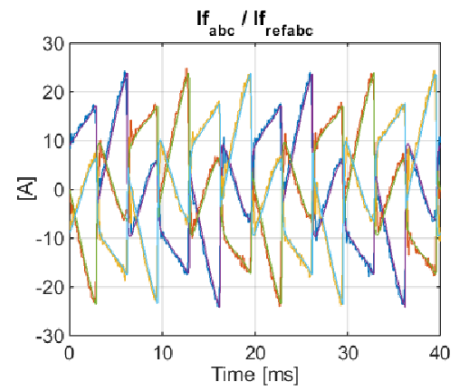
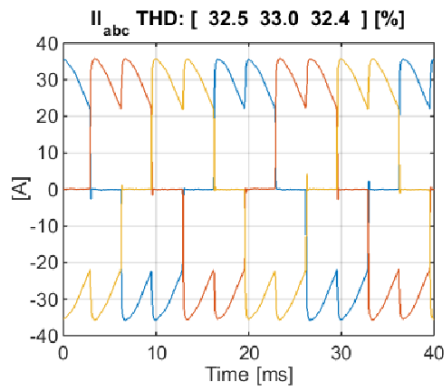
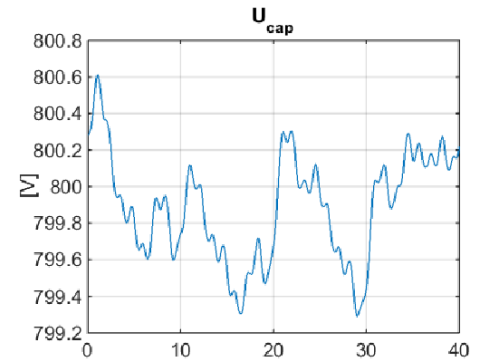
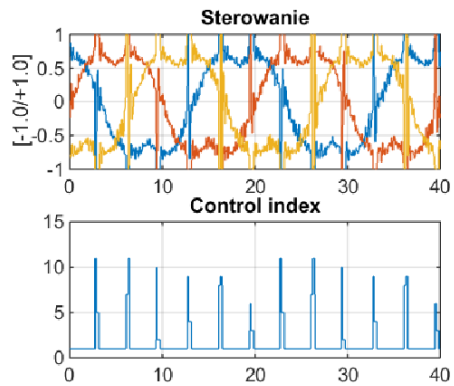
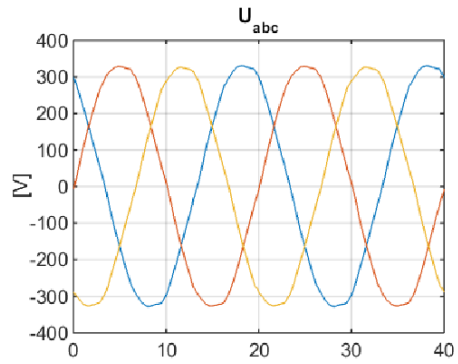
Udcmin

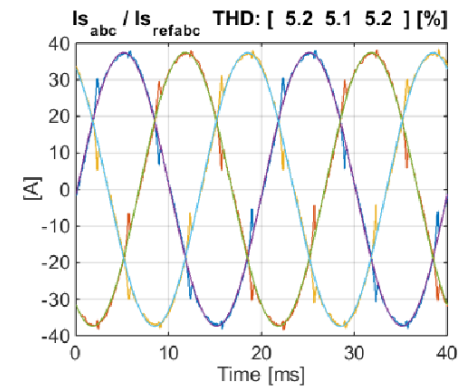
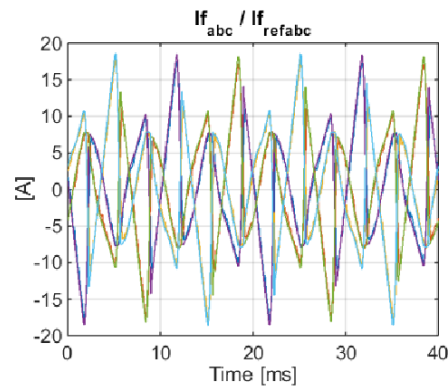
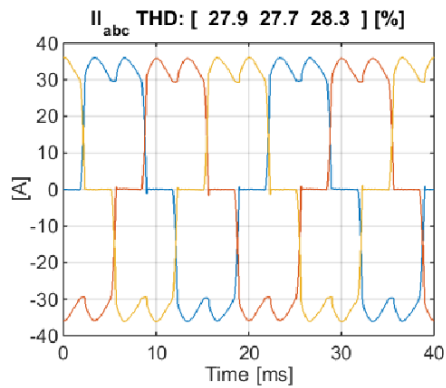
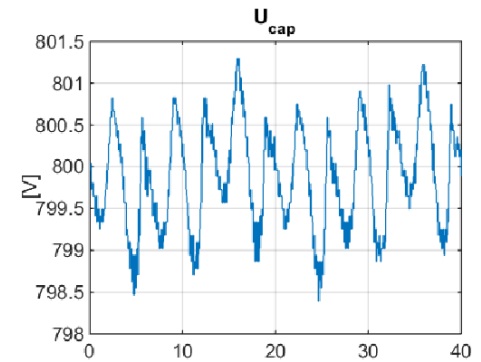
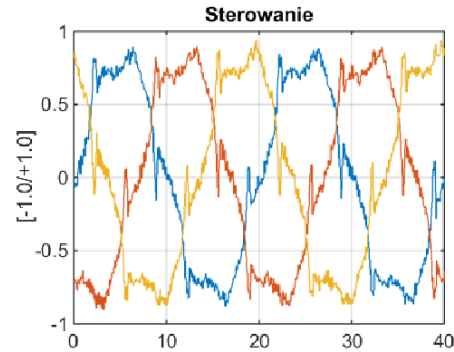
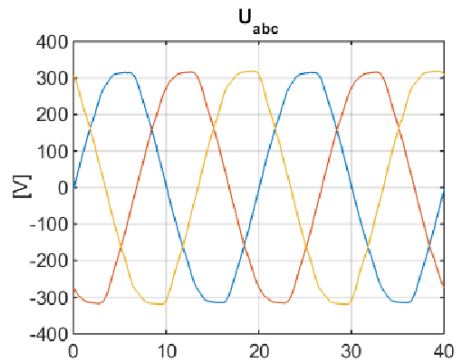
Udcmax

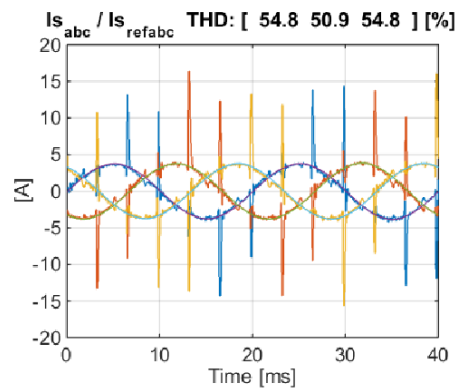
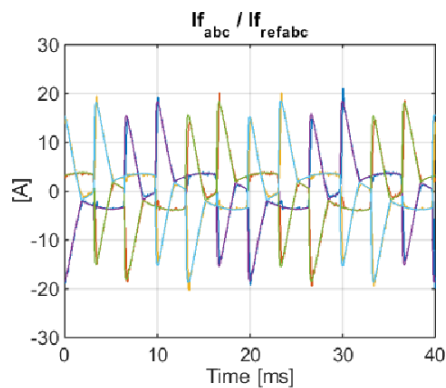
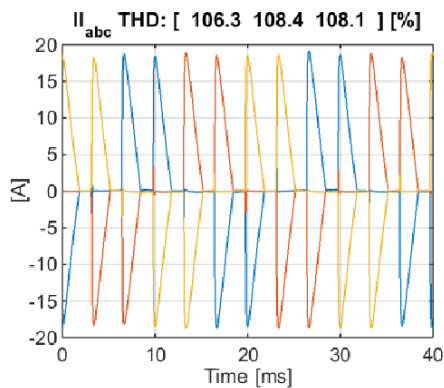
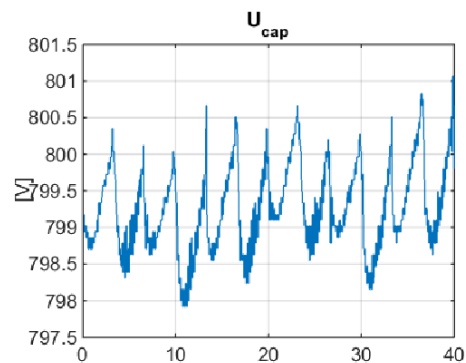
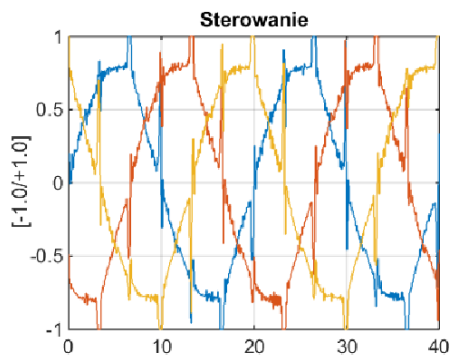
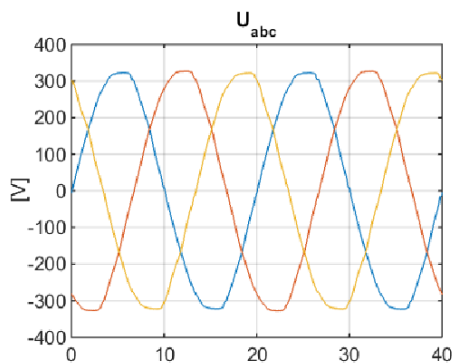
Człony heurystyczne:

- Przewidywanie sygnału okresowego
- Repetitive control (ok. 5% zakresu sterowania)

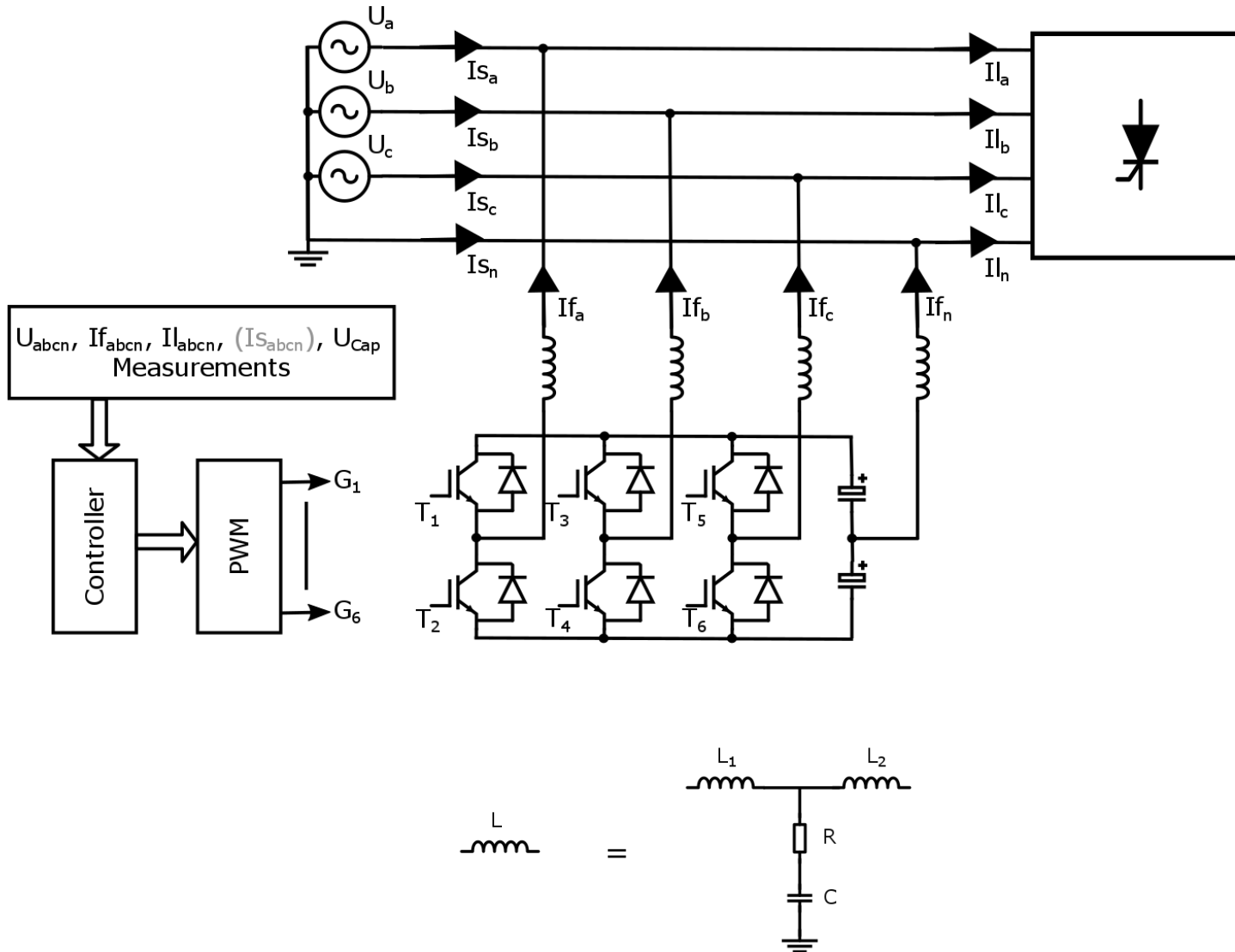








Filtr aktywny – zasada pracy, schemat 3W oraz 4W - FCzŁ

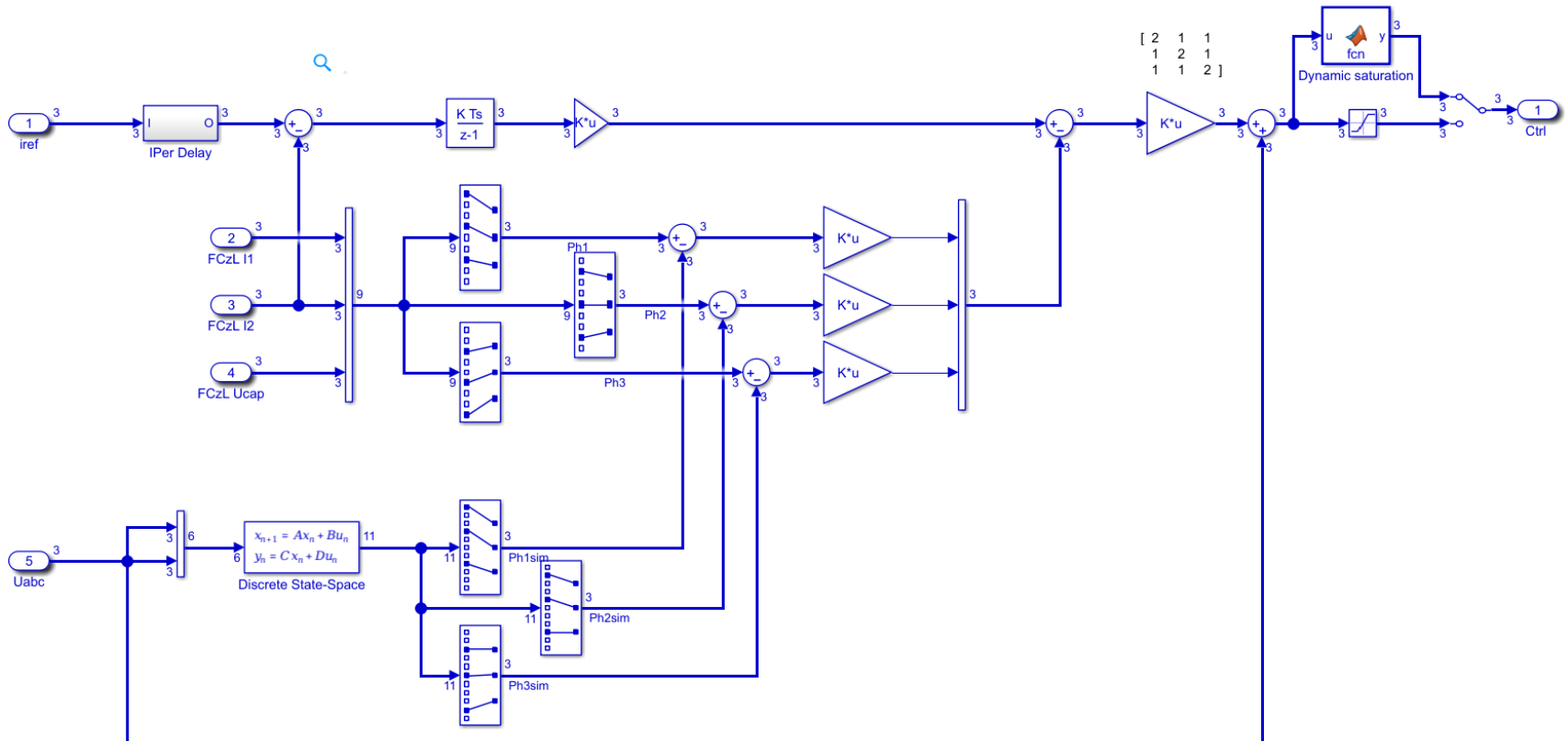


Filtr aktywny – zasada pracy, schemat 3W oraz 4W - FCzŁ

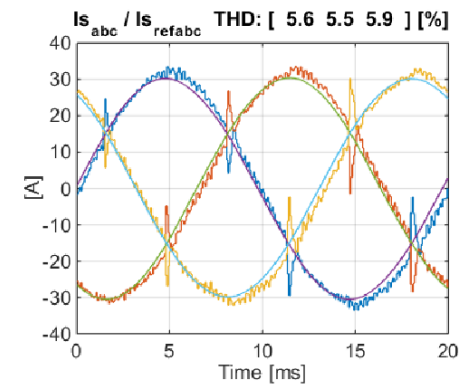
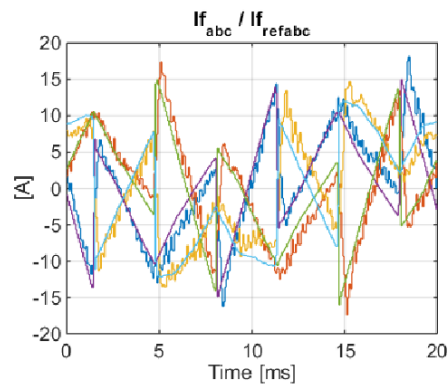
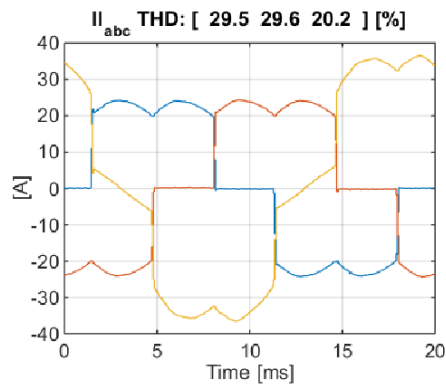
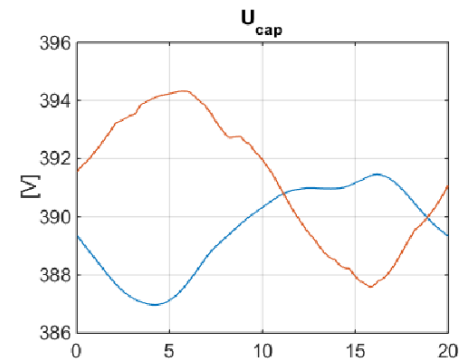
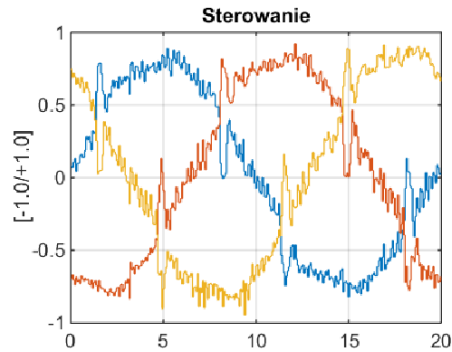
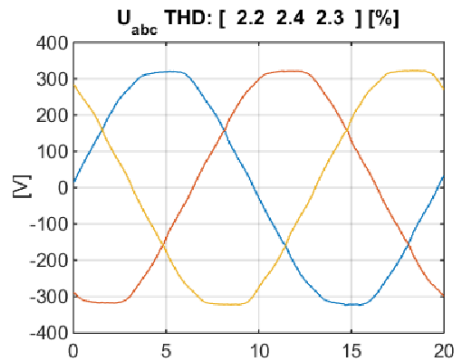
$$\begin{bmatrix} I_{1a} \\ I_{1b} \\ I_{1c} \\ I_{2a} \\ I_{2b} \\ I_{2c} \\ I_{2n} \\ U_{ca} \\ U_{cb} \\ U_{cc} \\ U_{cn} \end{bmatrix} = \begin{bmatrix} \frac{4R + 4R_s}{4L_1} & 0 & 0 & \frac{3R}{4L_1} & -\frac{R}{4L_1} & -\frac{R}{4L_1} & -\frac{R}{4L_1} & -\frac{3}{4L_1} & \frac{1}{4L_1} & \frac{1}{4L_1} & \frac{1}{4L_1} \\ 0 & -\frac{4R + 4R_s}{4L_1} & 0 & -\frac{R}{4L_1} & \frac{3R}{4L_1} & \frac{R}{4L_1} & -\frac{R}{4L_1} & \frac{1}{4L_1} & -\frac{3}{4L_1} & \frac{1}{4L_1} & \frac{1}{4L_1} \\ 0 & 0 & -\frac{4R + 4R_s}{4L_1} & \frac{R}{4L_1} & -\frac{R}{4L_1} & \frac{3R}{4L_1} & -\frac{R}{4L_1} & \frac{1}{4L_1} & \frac{1}{4L_1} & -\frac{3}{4L_1} & \frac{1}{4L_1} \\ \frac{R}{L_2} & 0 & 0 & -\frac{R + R_s}{L_2} & 0 & 0 & 0 & \frac{1}{L_2} & 0 & 0 & 0 \\ 0 & \frac{R}{L_2} & 0 & 0 & -\frac{R + R_s}{L_2} & 0 & 0 & 0 & \frac{1}{L_2} & 0 & 0 \\ 0 & 0 & \frac{R}{L_2} & 0 & 0 & -\frac{R + R_s}{L_2} & 0 & 0 & 0 & \frac{1}{L_2} & 0 \\ -\frac{R}{L_2} & -\frac{R}{L_2} & -\frac{R}{L_2} & 0 & 0 & 0 & -\frac{R + R_s}{L_2} & 0 & 0 & 0 & \frac{1}{L_2} \\ \frac{1}{C} & 0 & 0 & -\frac{1}{C} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{C} & 0 & 0 & -\frac{1}{C} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{C} & 0 & 0 & -\frac{1}{C} & 0 & 0 & 0 & 0 & 0 \\ -\frac{1}{C} & -\frac{1}{C} & -\frac{1}{C} & 0 & 0 & 0 & -\frac{1}{C} & 0 & 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} \frac{3}{4L_1} & -\frac{1}{4L_1} & -\frac{1}{4L_1} & 0 & 0 & 0 \\ -\frac{1}{4L_1} & \frac{3}{4L_1} & -\frac{1}{4L_1} & 0 & 0 & 0 \\ \frac{1}{4L_1} & -\frac{1}{4L_1} & \frac{3}{4L_1} & 0 & 0 & 0 \\ 0 & 0 & 0 & -\frac{1}{L_2} & 0 & 0 \\ 0 & 0 & 0 & 0 & -\frac{1}{L_2} & 0 \\ 0 & 0 & 0 & 0 & 0 & -\frac{1}{L_2} \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_{1a} \\ I_{1b} \\ I_{1c} \\ I_{2a} \\ I_{2b} \\ I_{2c} \\ I_{2n} \\ U_{ca} \\ U_{cb} \\ U_{cc} \\ U_{cn} \end{bmatrix} + \begin{bmatrix} E_a \\ E_b \\ E_c \\ U_{sa} \\ U_{sb} \\ U_{sc} \end{bmatrix}$$

Filtr aktywny – zasada pracy, schemat 3W oraz 4W - FCzŁ

Regulator 4W FCzŁ

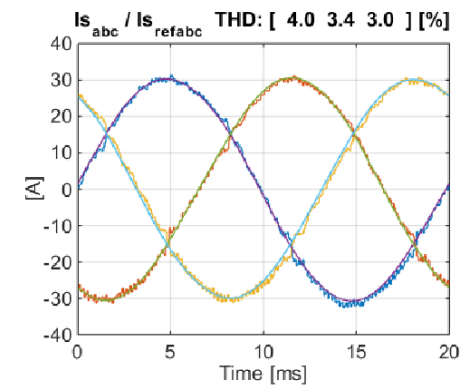
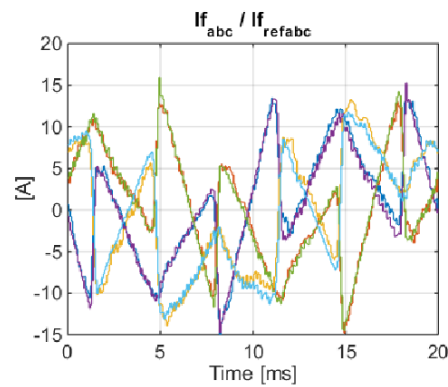
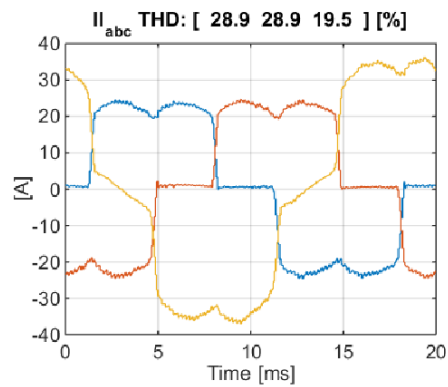
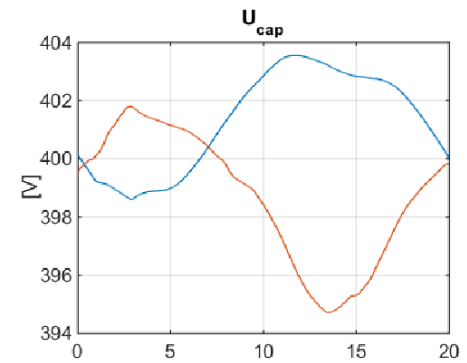
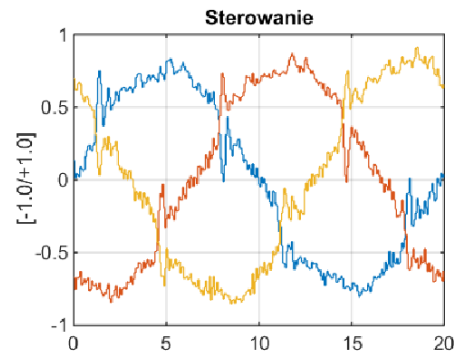
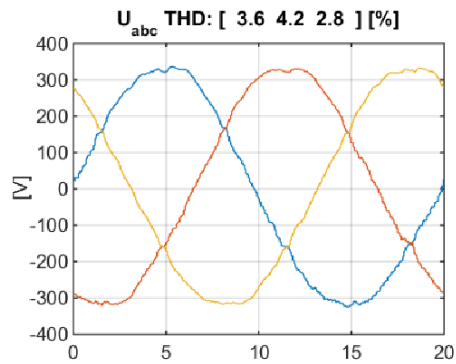


Filtr aktywny – zasada pracy, schemat 3W oraz 4W - FCzŁ

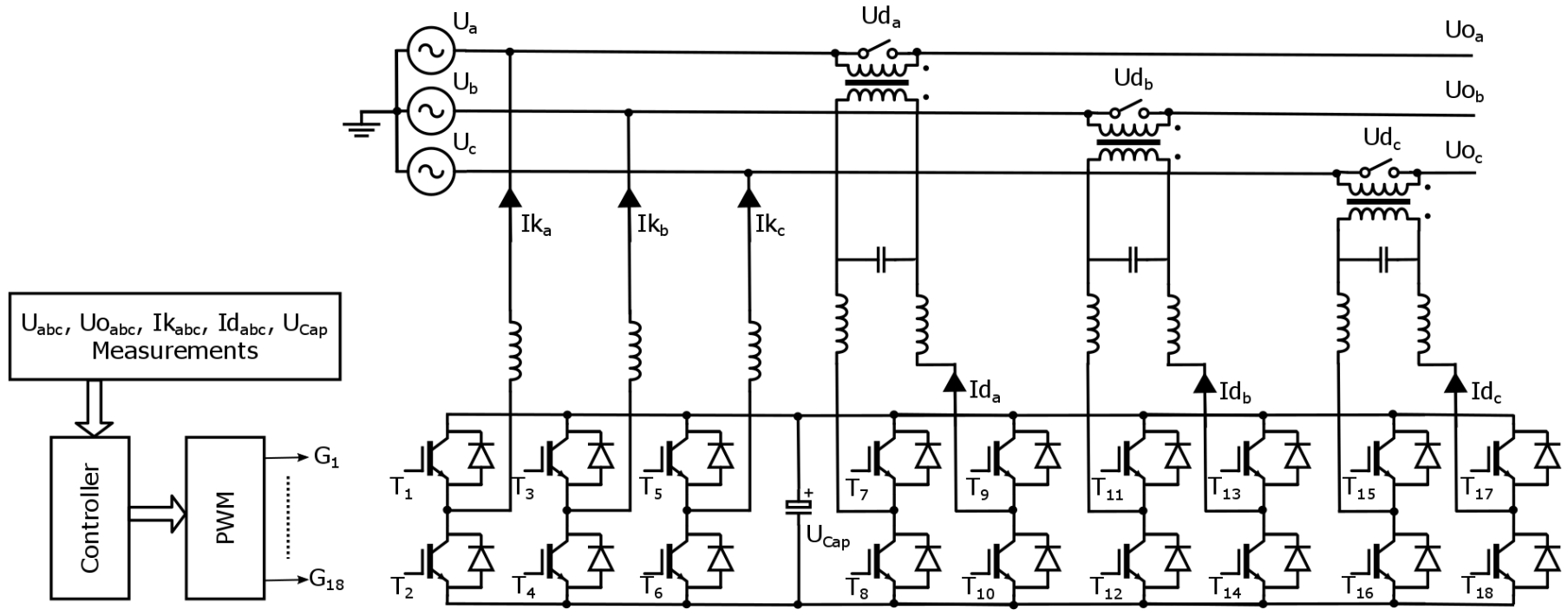


Filtr aktywny – zasada pracy, schemat 3W oraz 4W - FCzŁ

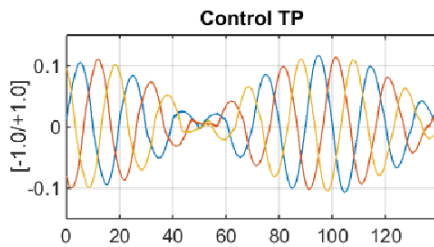
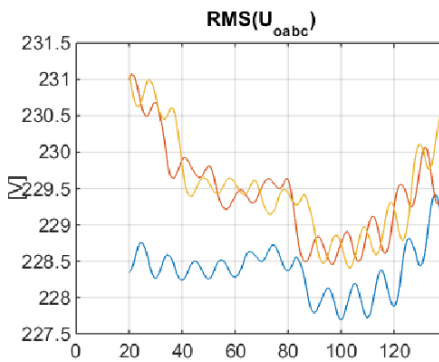
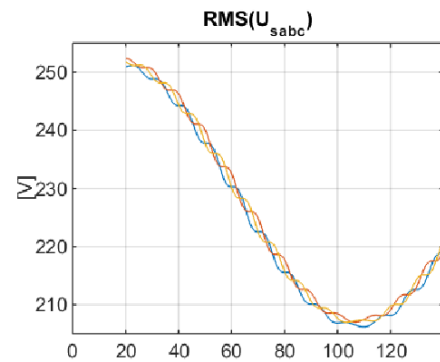
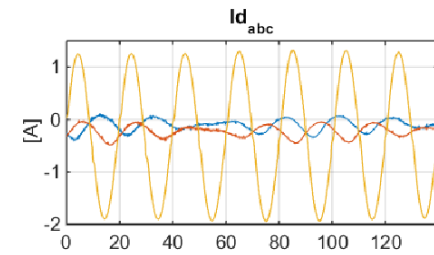
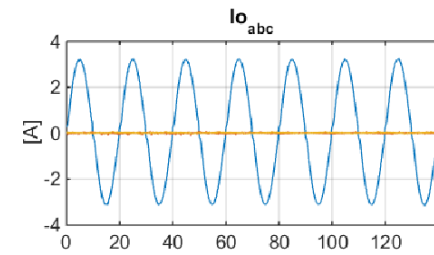
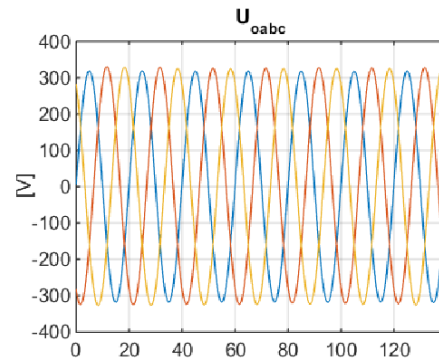
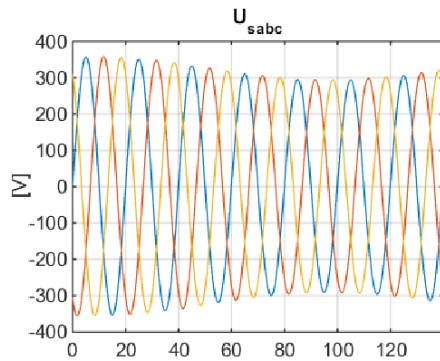
Szeregowo z siecią 0.8 mH



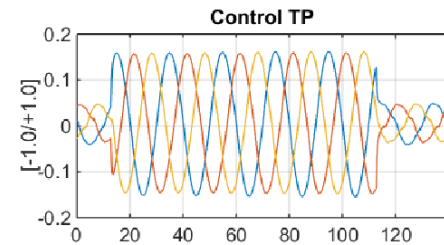
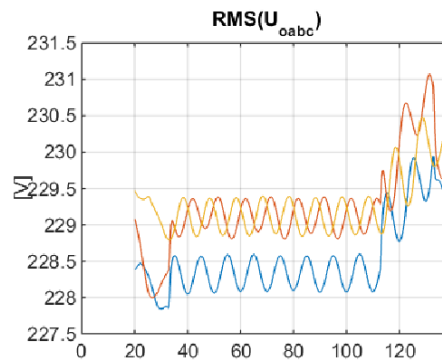
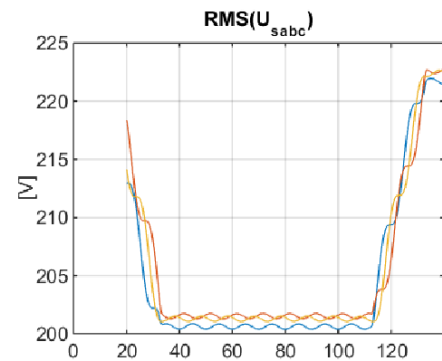
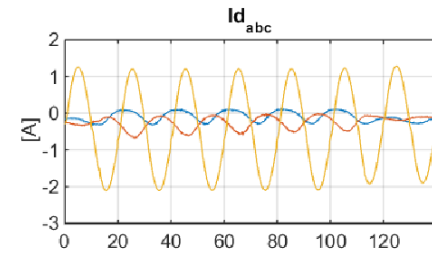
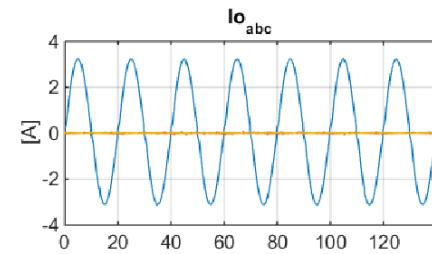
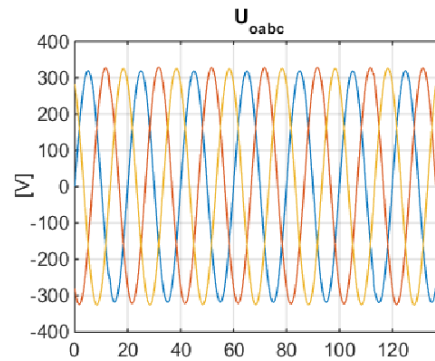
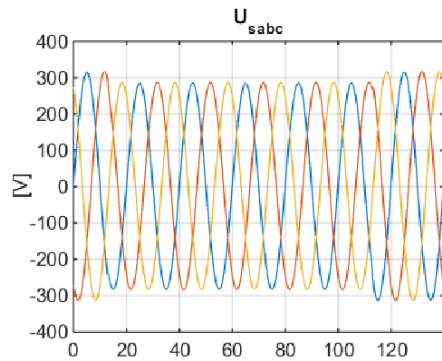
Dynamiczny stabilizator napięcia - zasada pracy, schemat, wyniki



Dynamiczny stabilizator napięcia - zasada pracy, schemat, wyniki



Dynamiczny stabilizator napięcia - zasada pracy, schemat, wyniki









Wady

- Brak dobrego regulatora dla wersji z FCzŁ – PWM / nieliniowość
- Częstotliwość kluczowania – przejście na węglík krzemu SiC lub azotek galu GaN
- Sprzęganie poprzez pamięć notatnikową