



AGH



Euro - Centrum

Studia Podyplomowe

EFEKTYWNE UŻYTKOWANIE ENERGII ELEKTRYCZNEJ

w ramach projektu

**Śląsko-Małopolskie Centrum Kompetencji
Zarządzania Energią**

Kompensacja mocy biernej

dr hab. inż. Zbigniew Hanzelka, prof. AGH



AGH



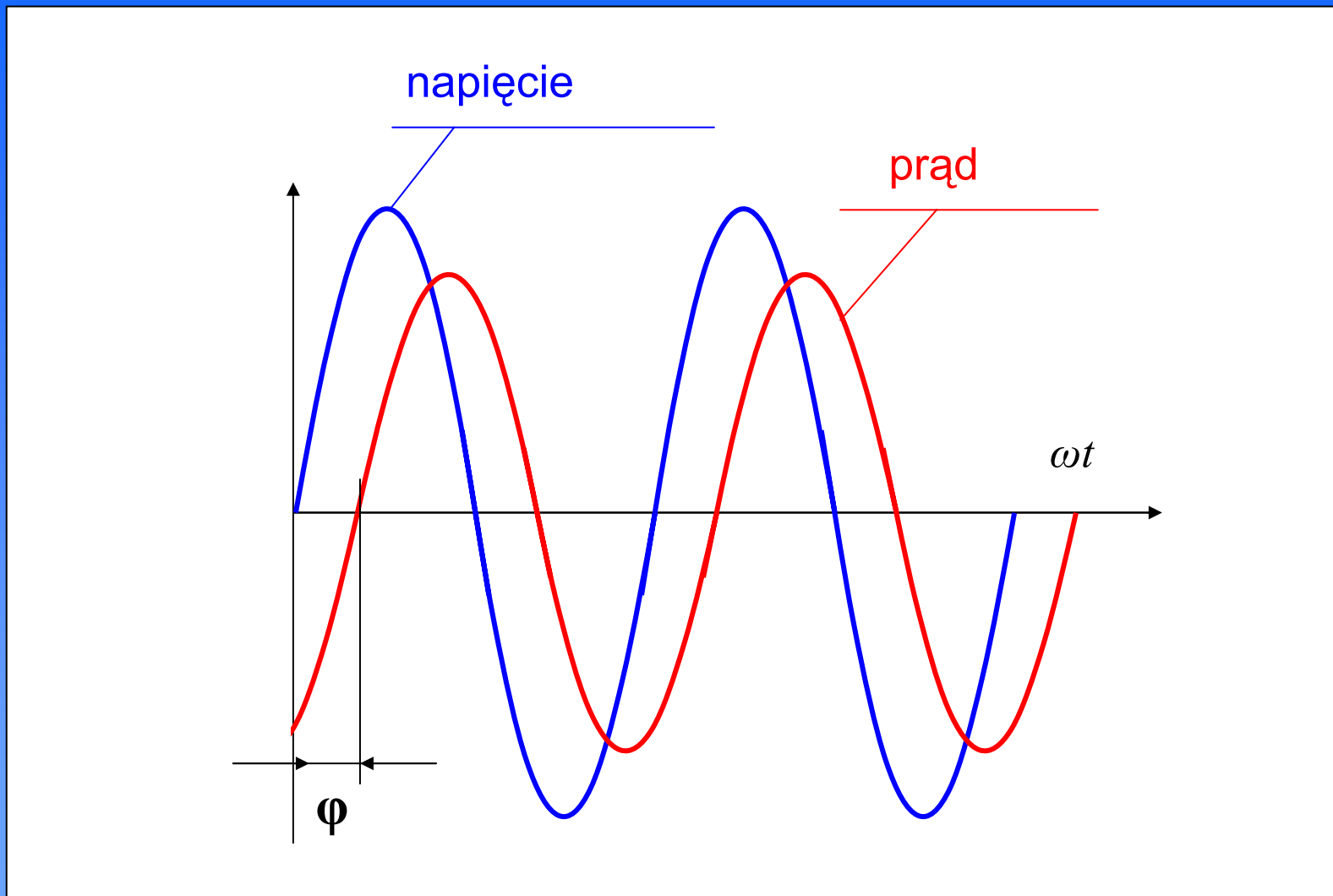
Akademia Górniczo-Hutnicza
Kraków

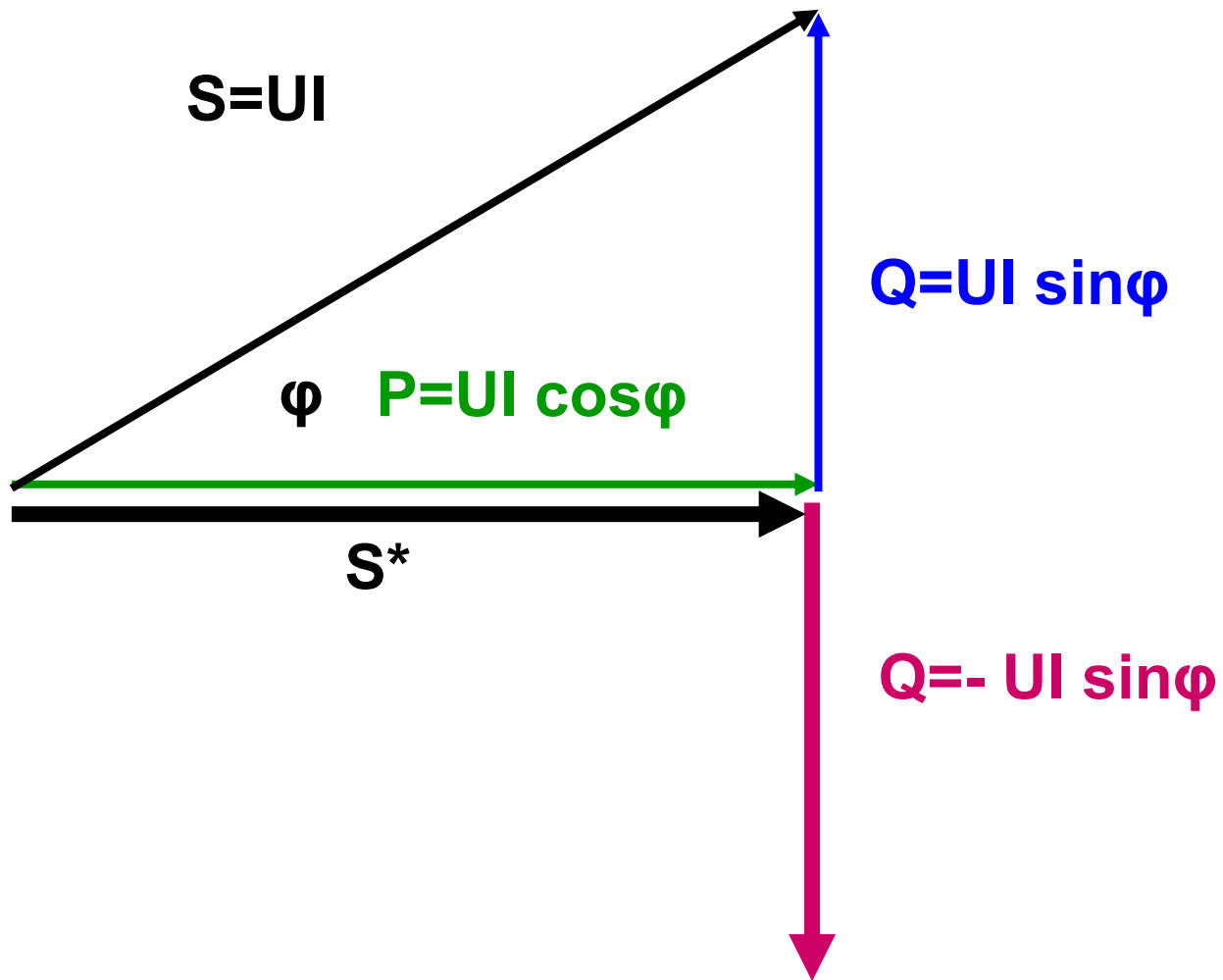
Zbigniew HANZELKA

Kompensacja mocy biernej

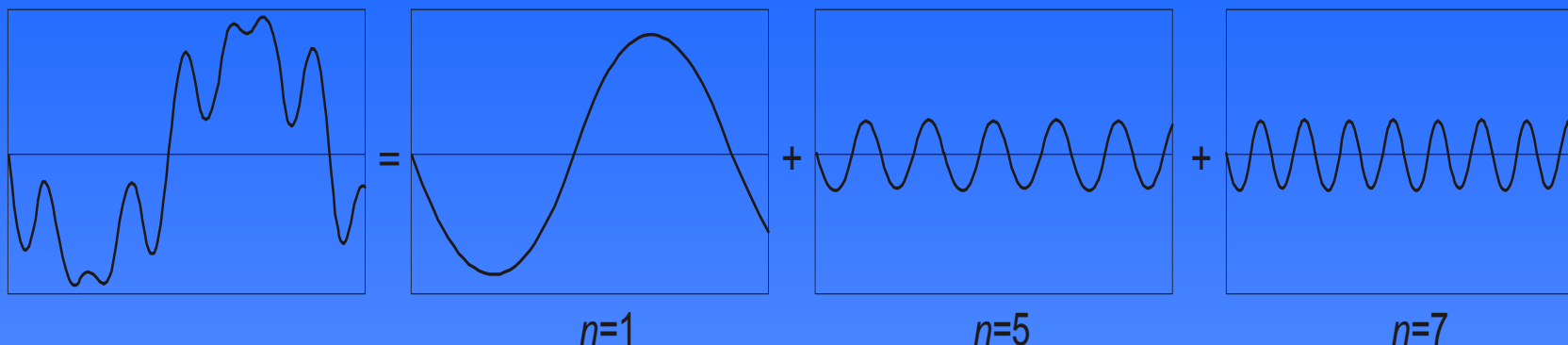
Kraków, marzec 2013 r.

DEFINICJE MOCY BIERNEJ





Analiza Fouriera

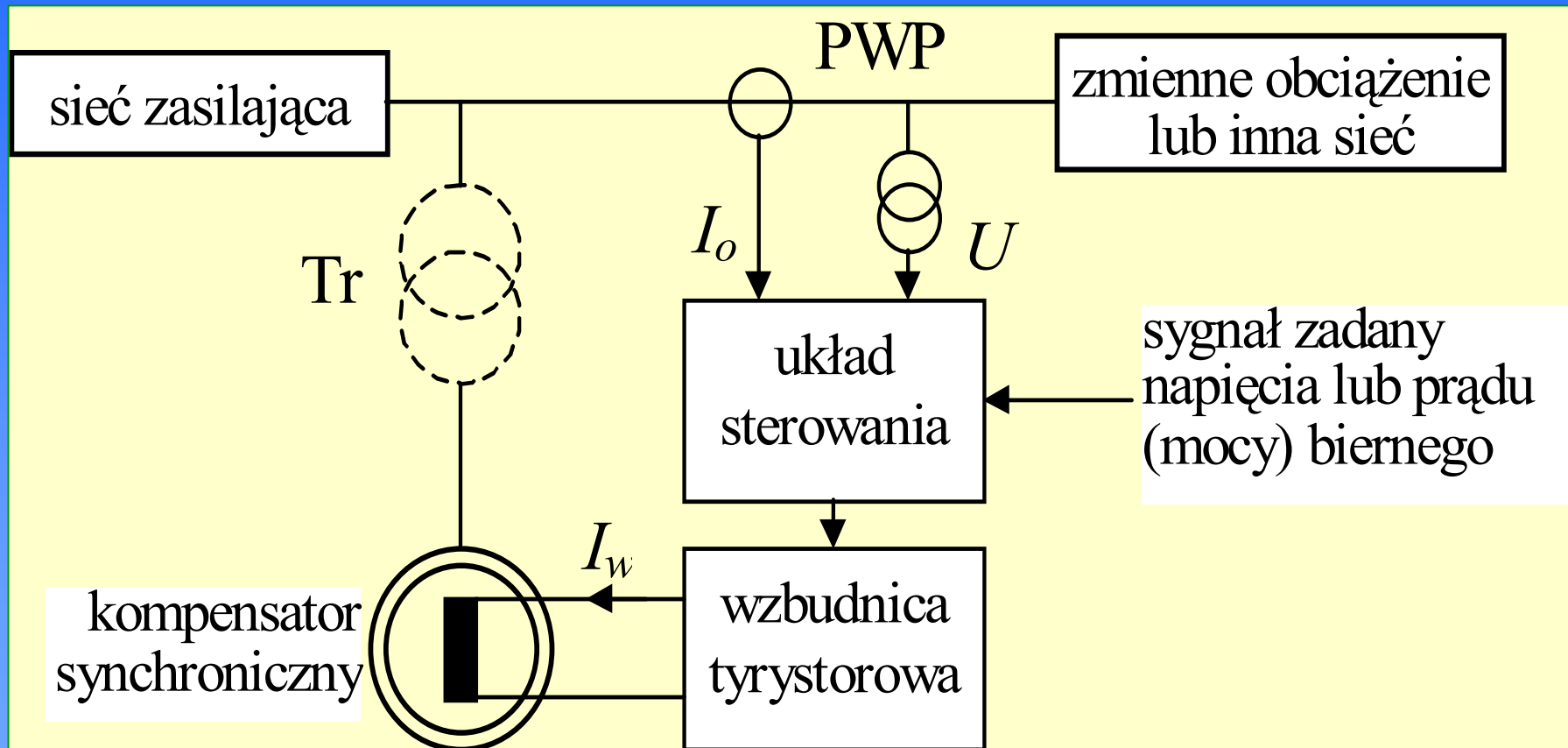


Cel kompensacji:

- kompensacja mocy biernej podstawowej harmonicznej
- eliminacja wybranych harmoniczných prądu (redukcja odkształcenia napięcia w PWP)

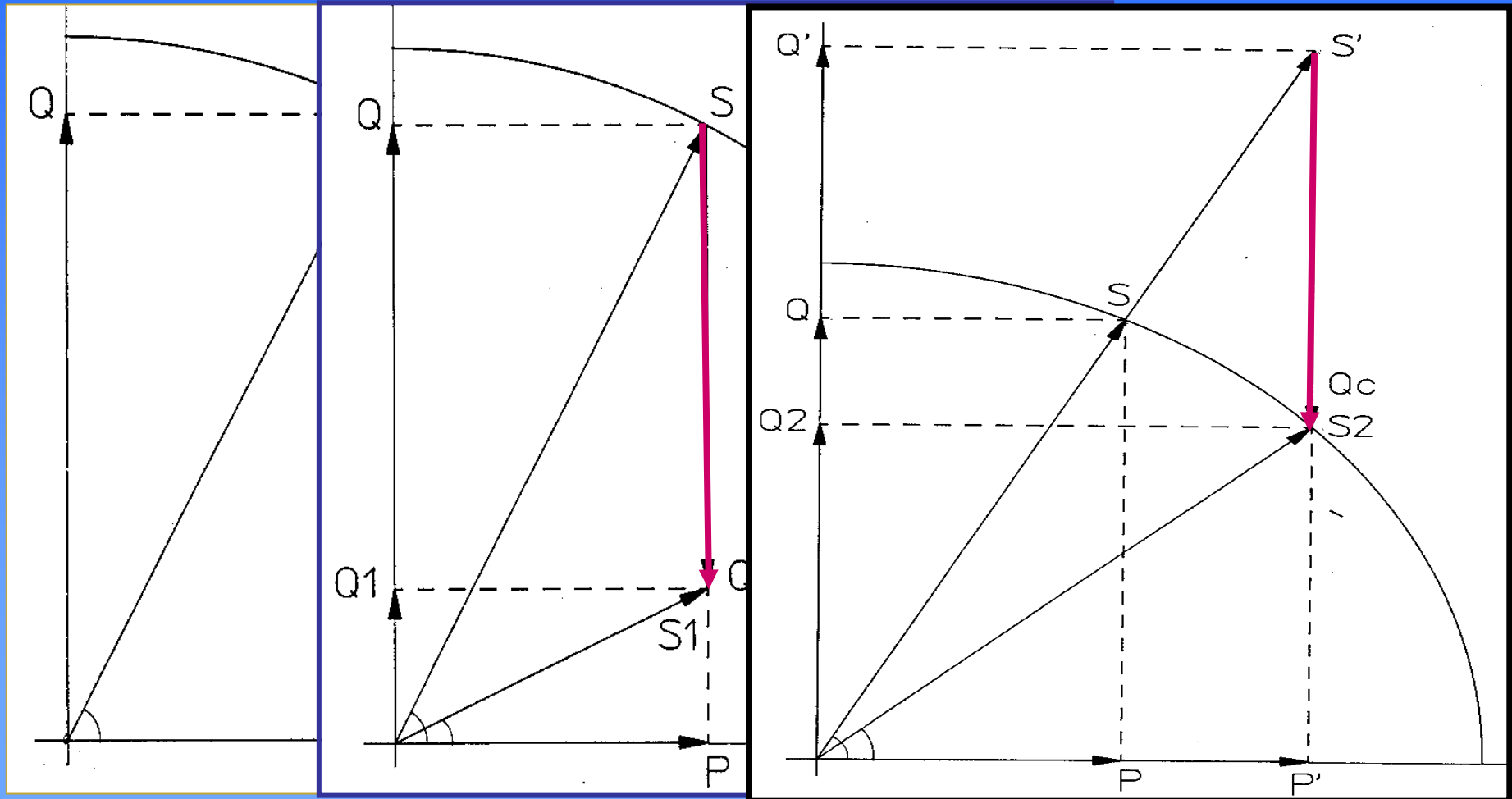
KOMPENSATOR WIRUJĄCY

Kompensatory synchroniczne

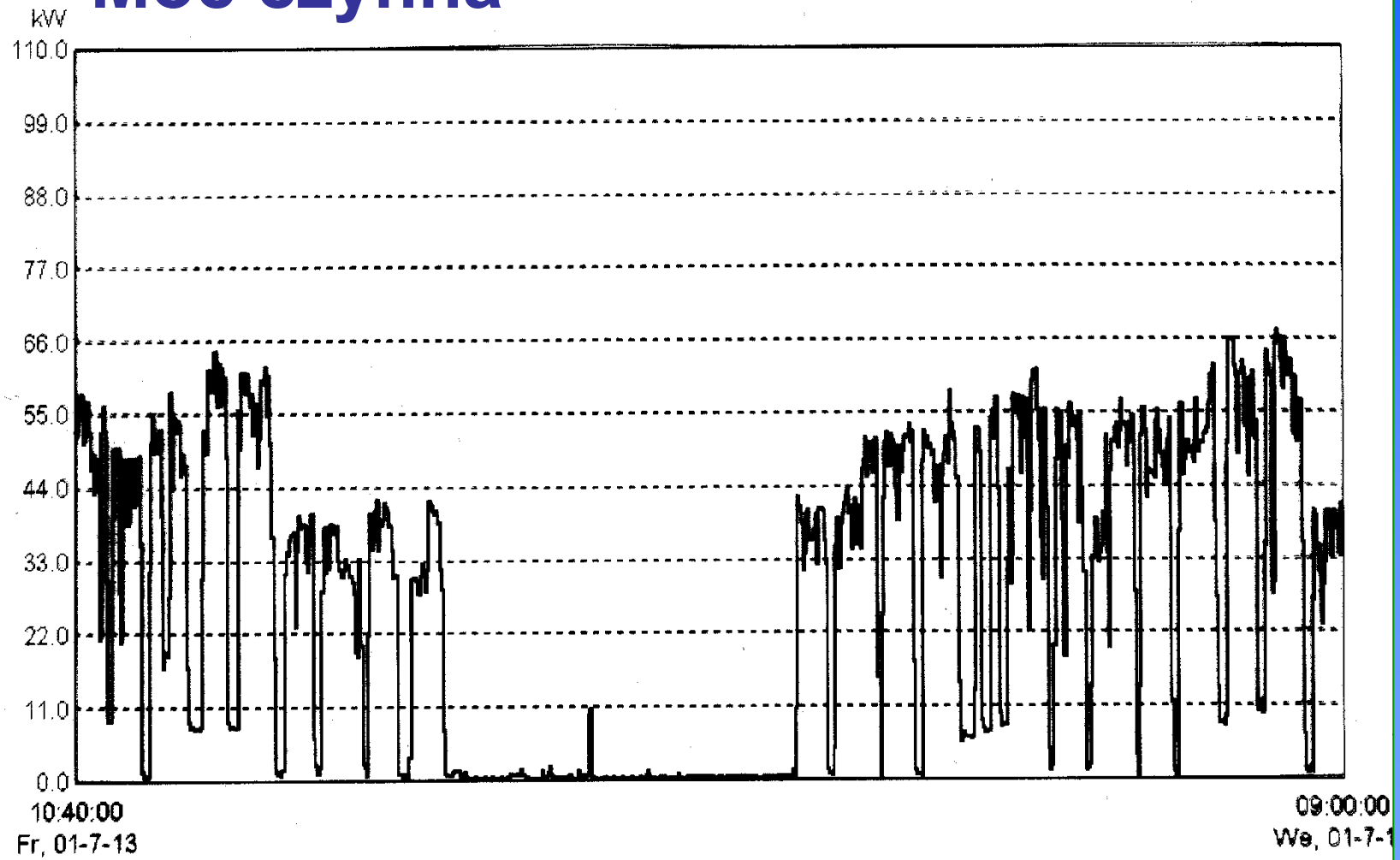


KONDENSATORY
KOMPENSACJA MOCY BIERNEJ

Kompensacja mocy biernej

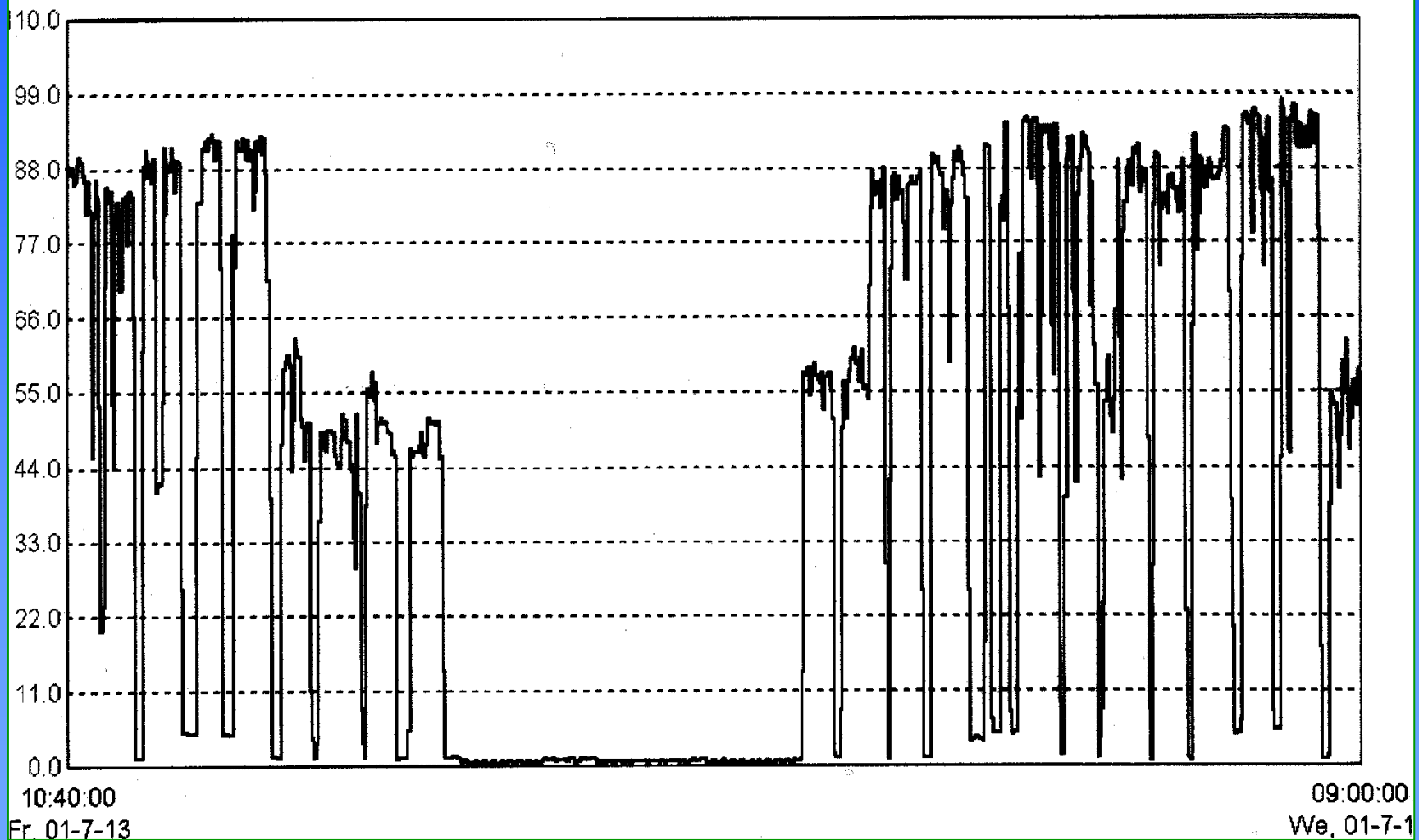


Moc czynna



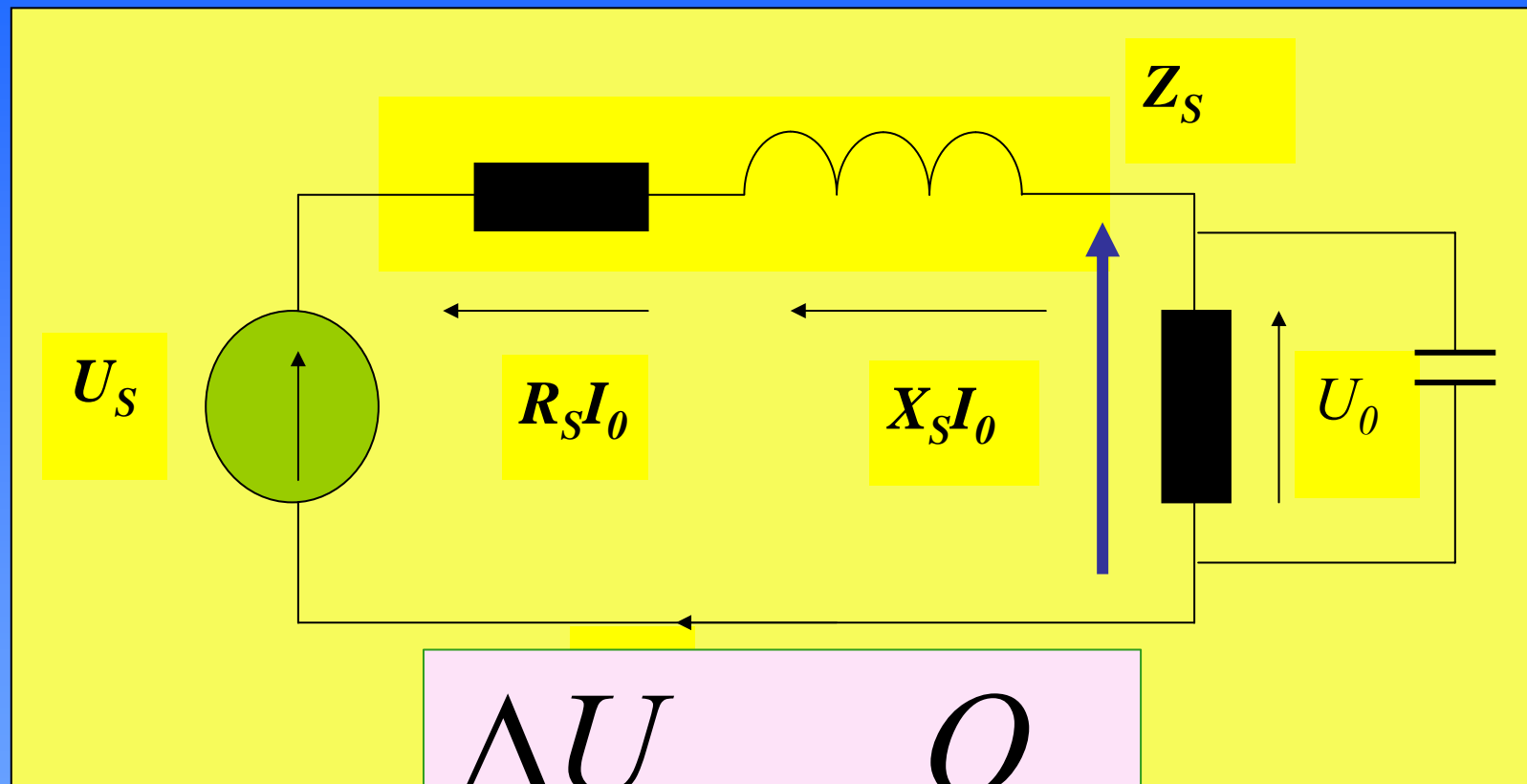
Moc bierna

kVar

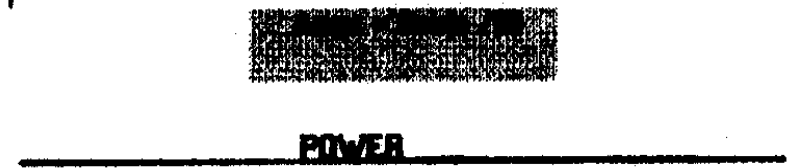
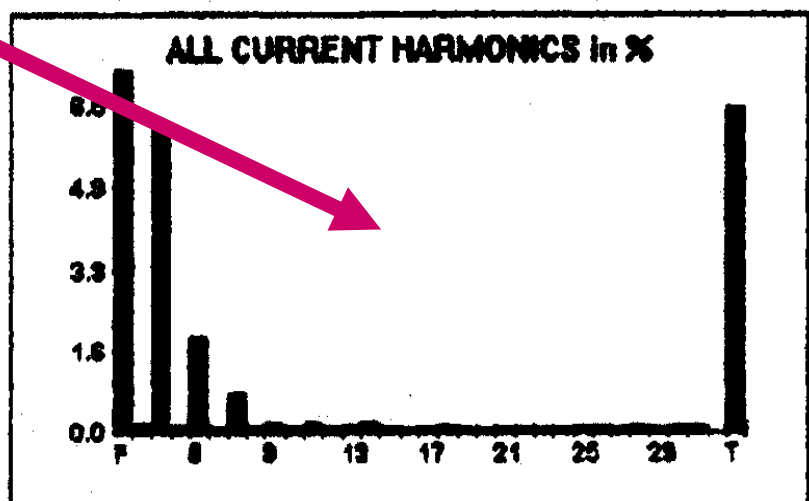
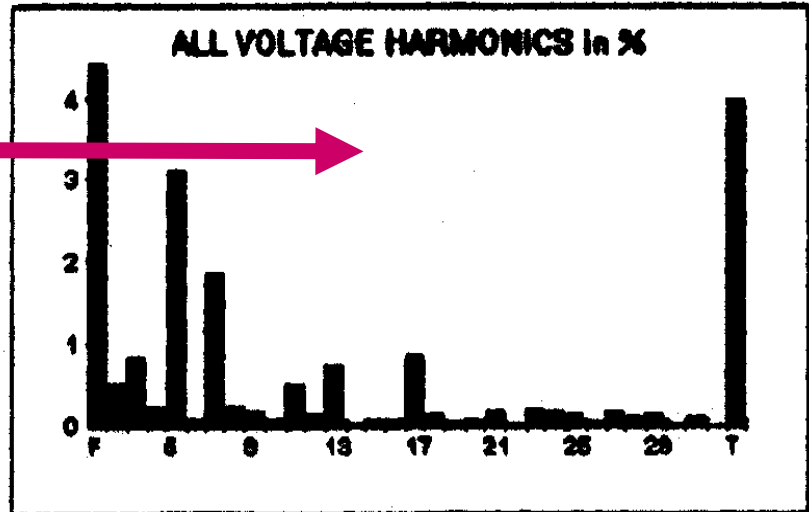
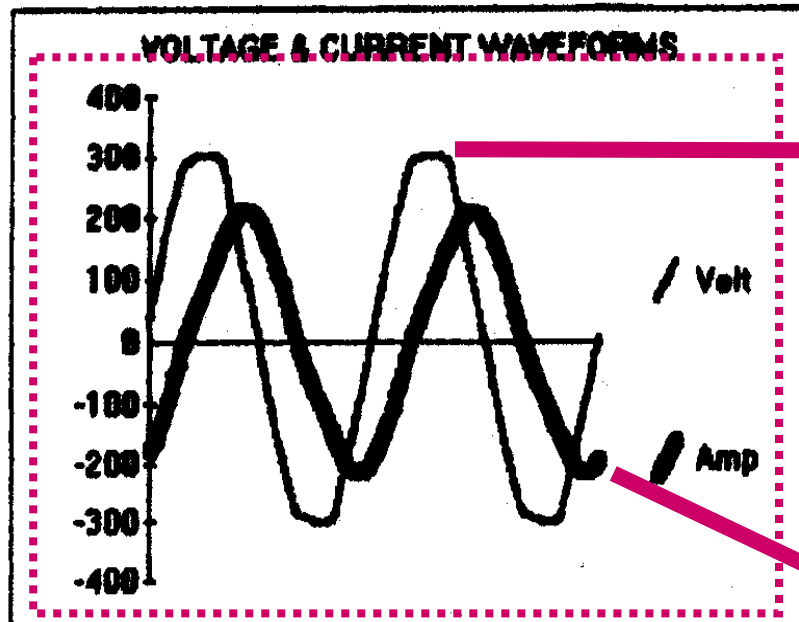


KONDENSATORY
STABILIZACJA NAPIĘCIA

Regulacja napięcia

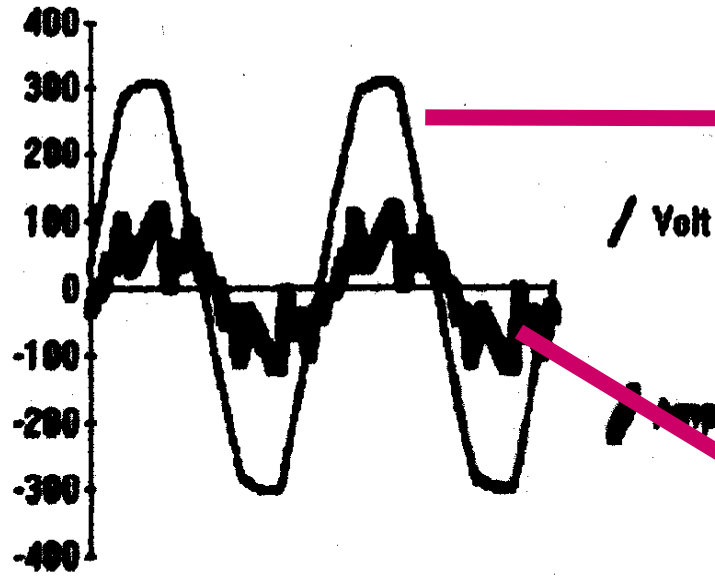


$$\frac{\Delta U}{U_0} \approx \frac{Q}{S_{ZW}}$$



Working Pwr	248.963848842383 W
Reactive Pwr	881.164245886468 VAR L
Apparent Pwr	942.794258488281 VA
Displacement Pwr	41.4287757873535 dVA
True Power Factor	.38734808886251 PF
Displacement PF	.388814032877789 dPF

VOLTAGE & CURRENT WAVEFORMS

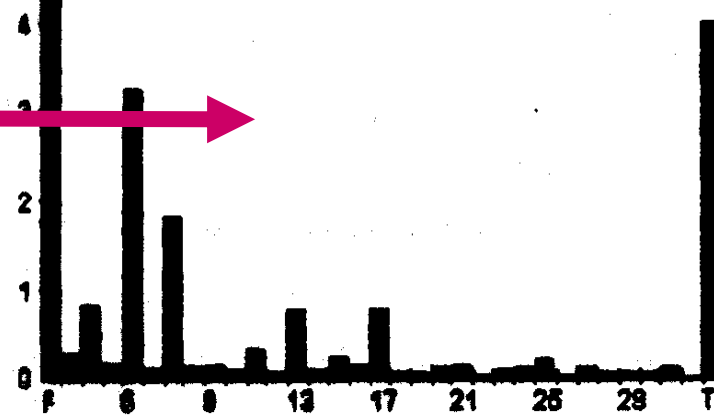


POWER

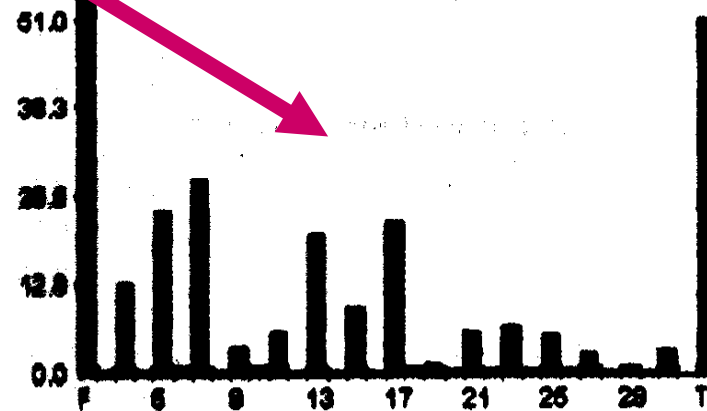
Working Pwr
 Reactive Pwr
 Apparent Pwr
 Displacement Pwr
 True Power Factor
 Displacement PF

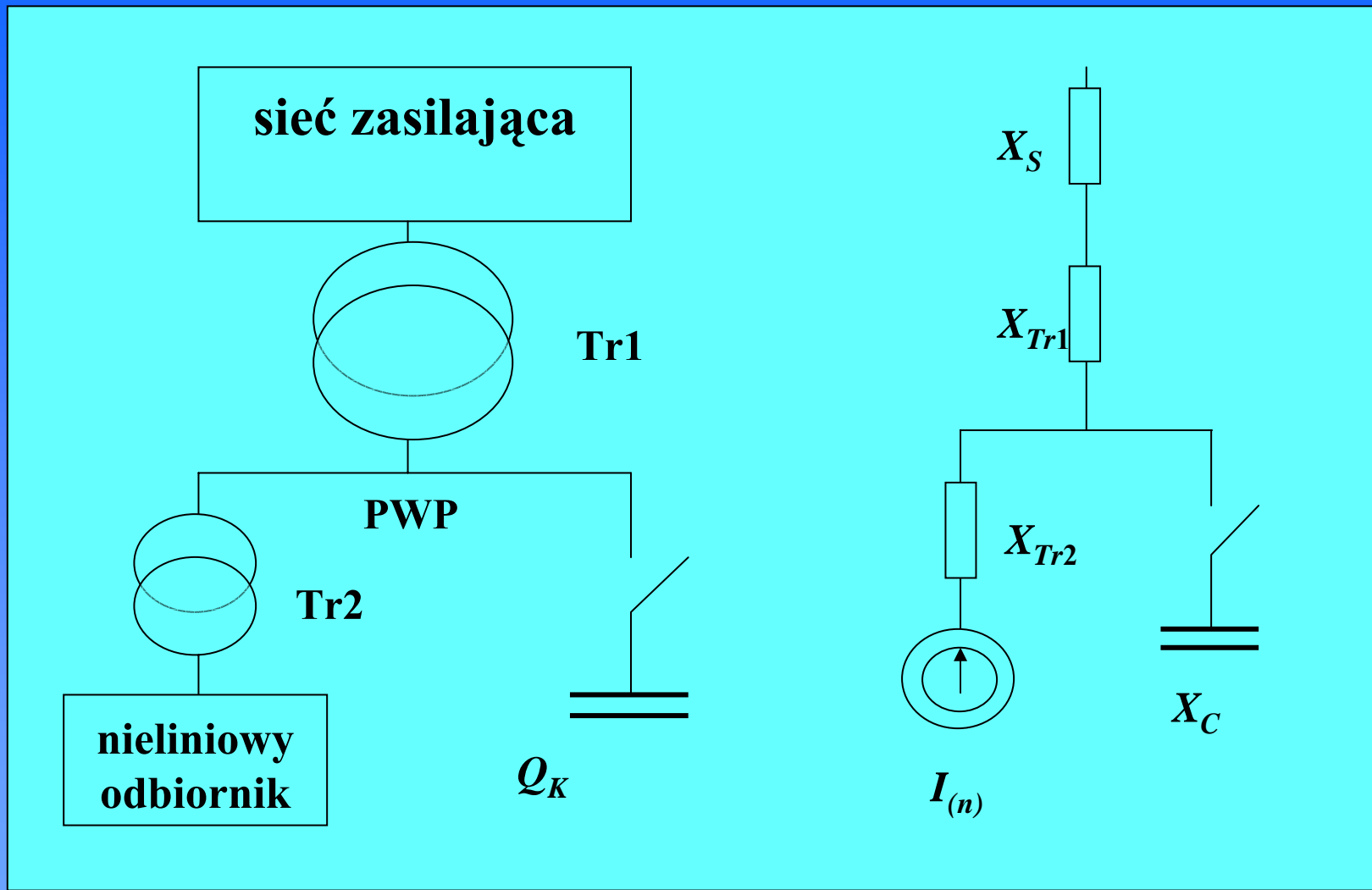
248.89123829986 W
 81.518898889477 VAR
 294.314049883816 VA
 132.965834284182 dVA
 .848841534423828 PF
 .945769688028783 dPF

ALL VOLTAGE HARMONICS in %

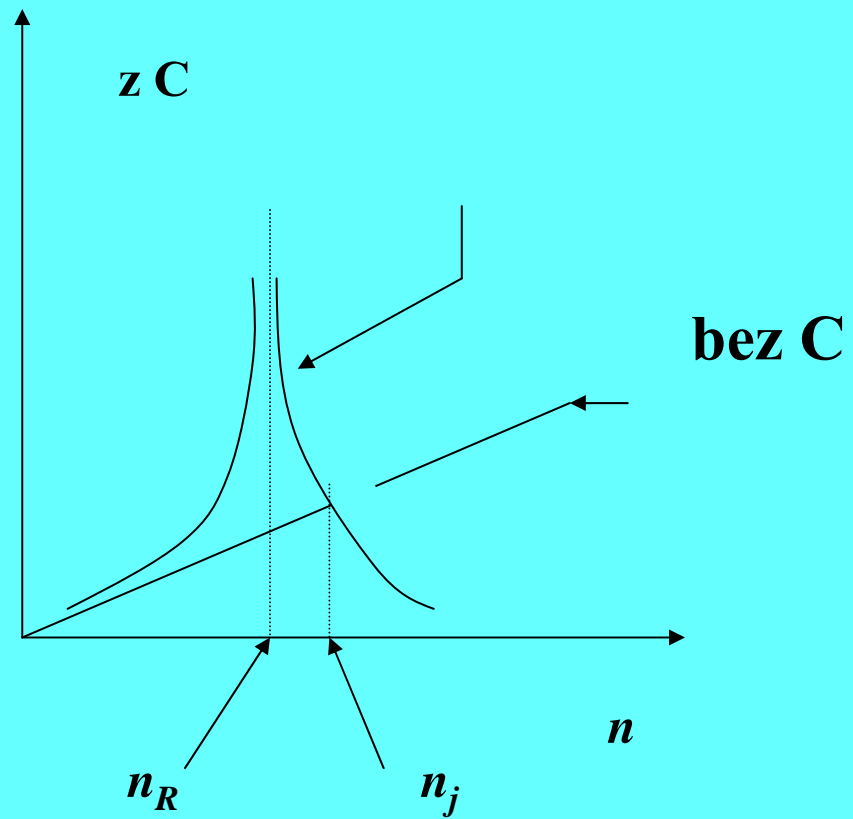


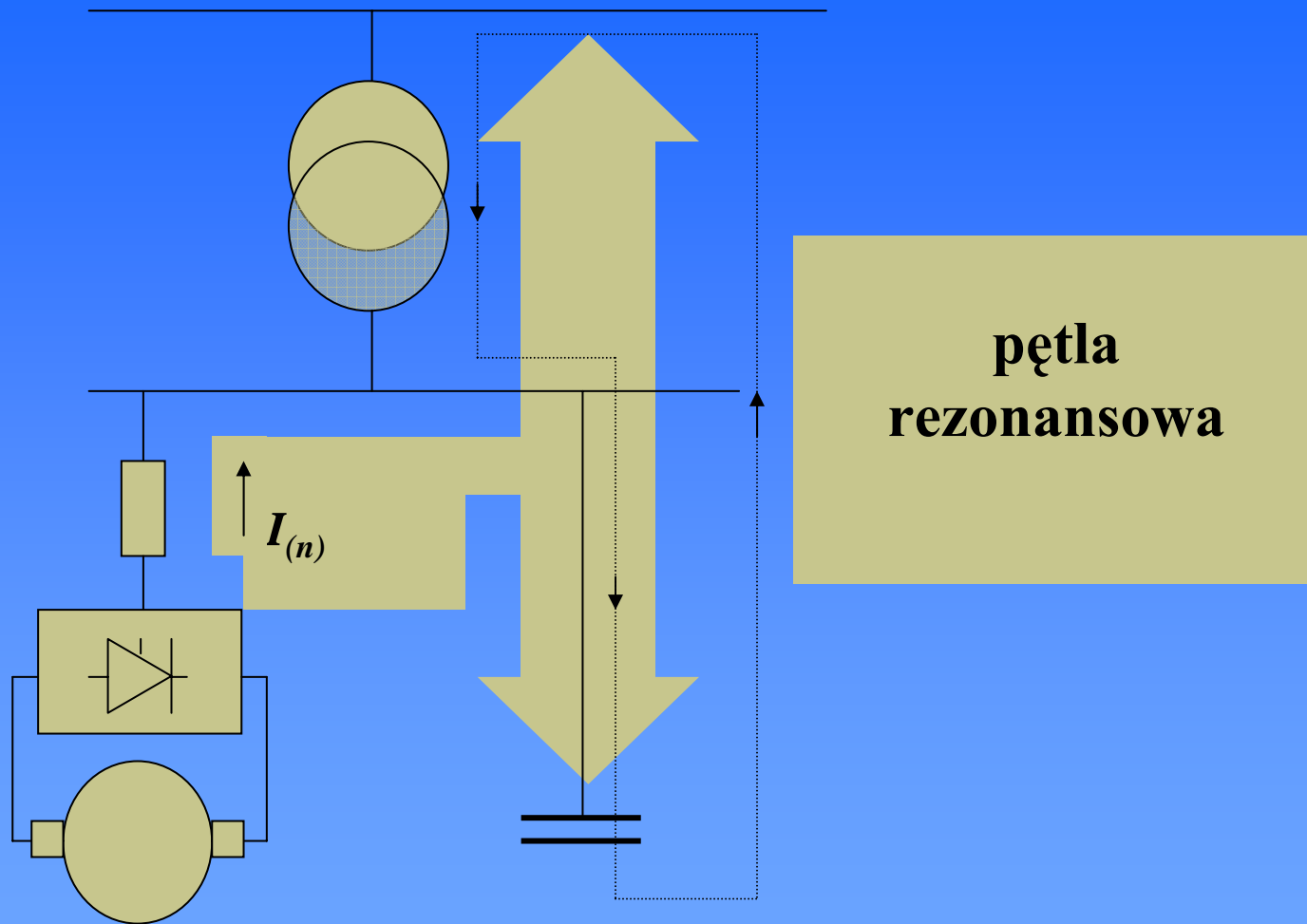
ALL CURRENT HARMONICS in %



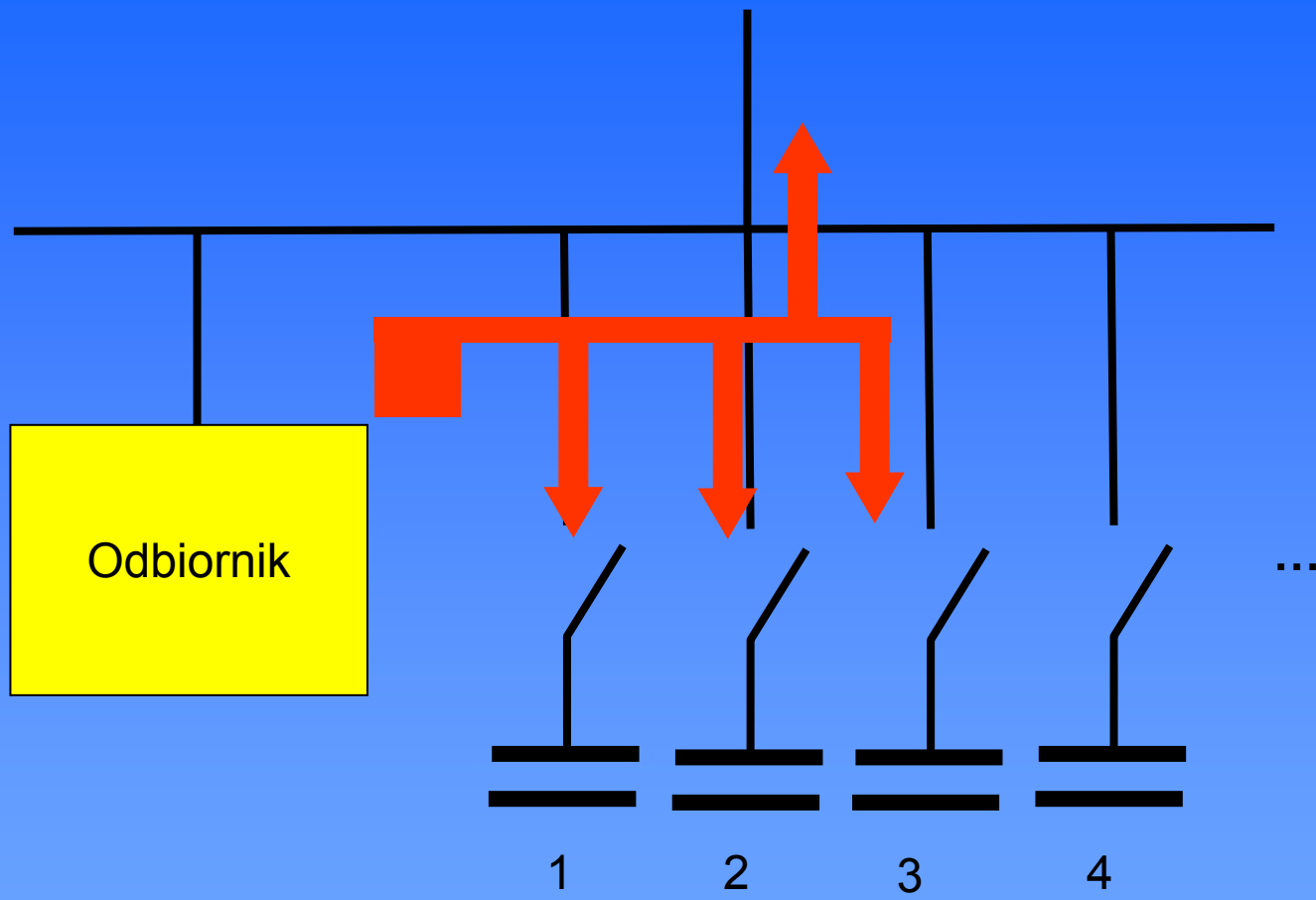


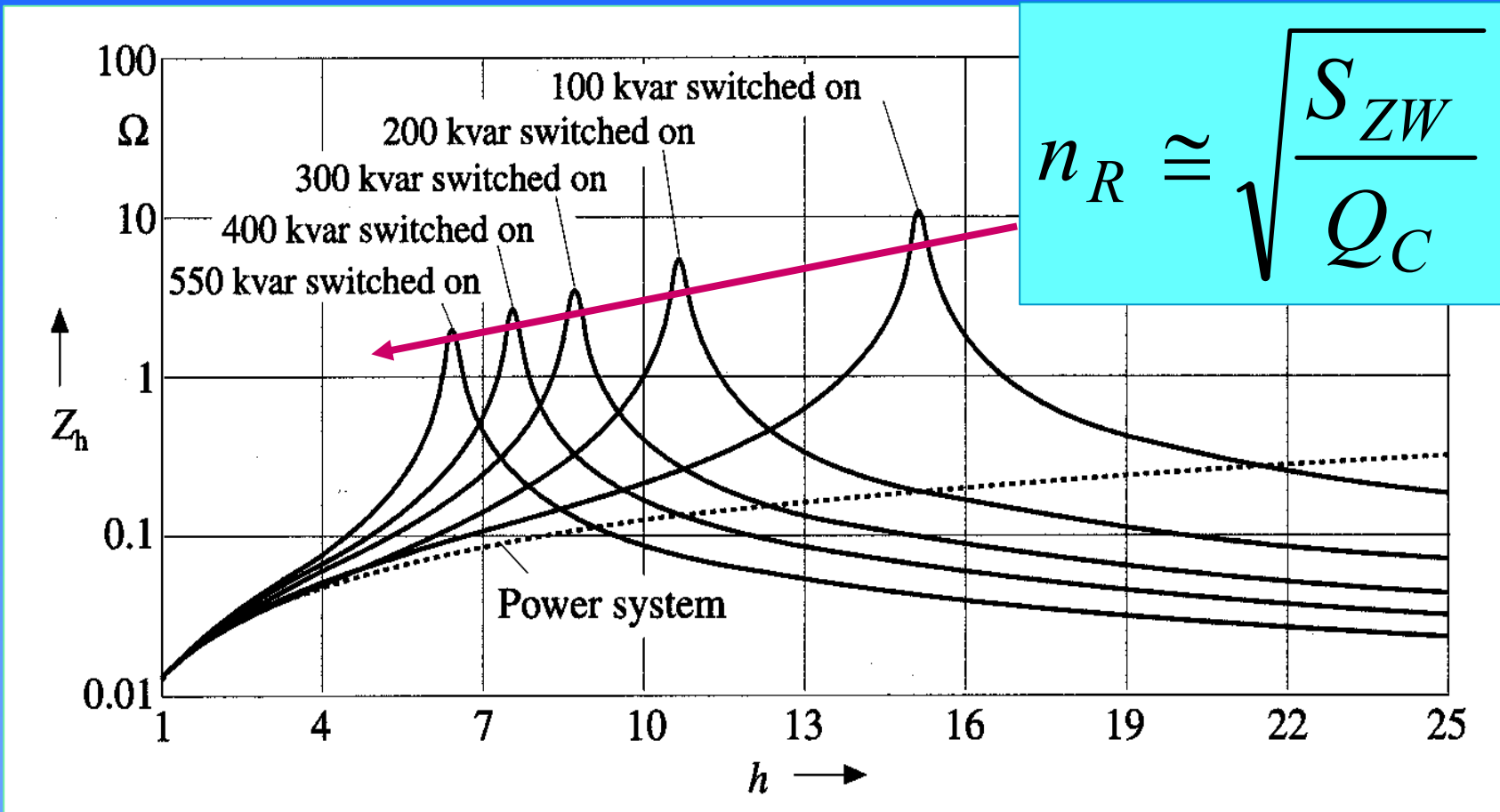
**impedancja
widziana z
zacisków
nie liniowego
odbiornika**



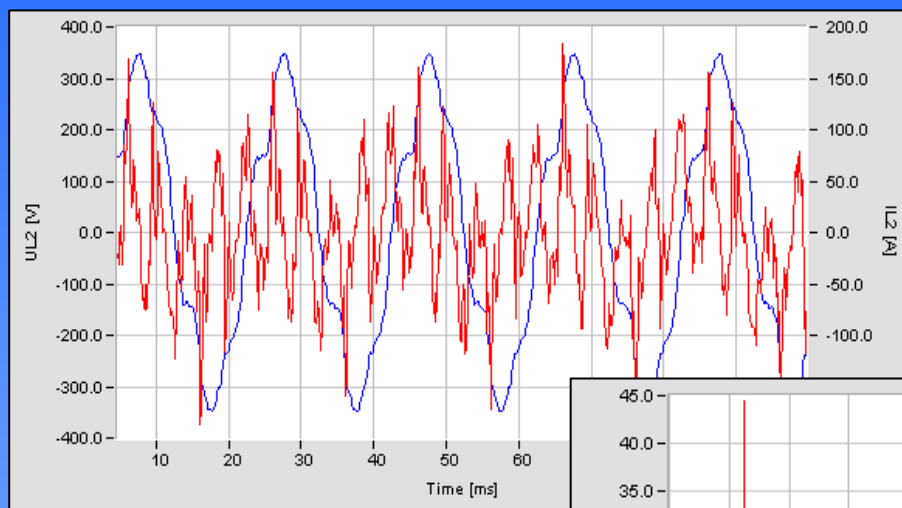


**pętla
rezonansowa**

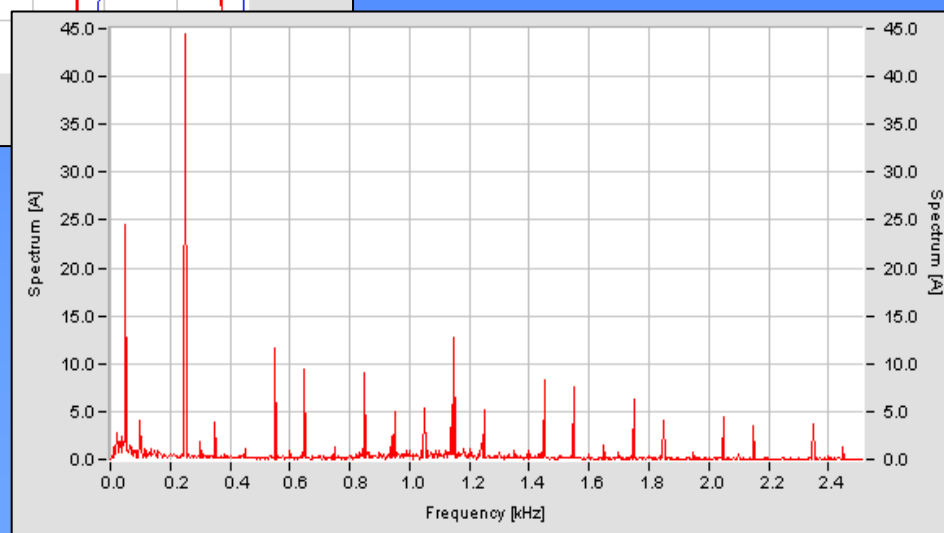




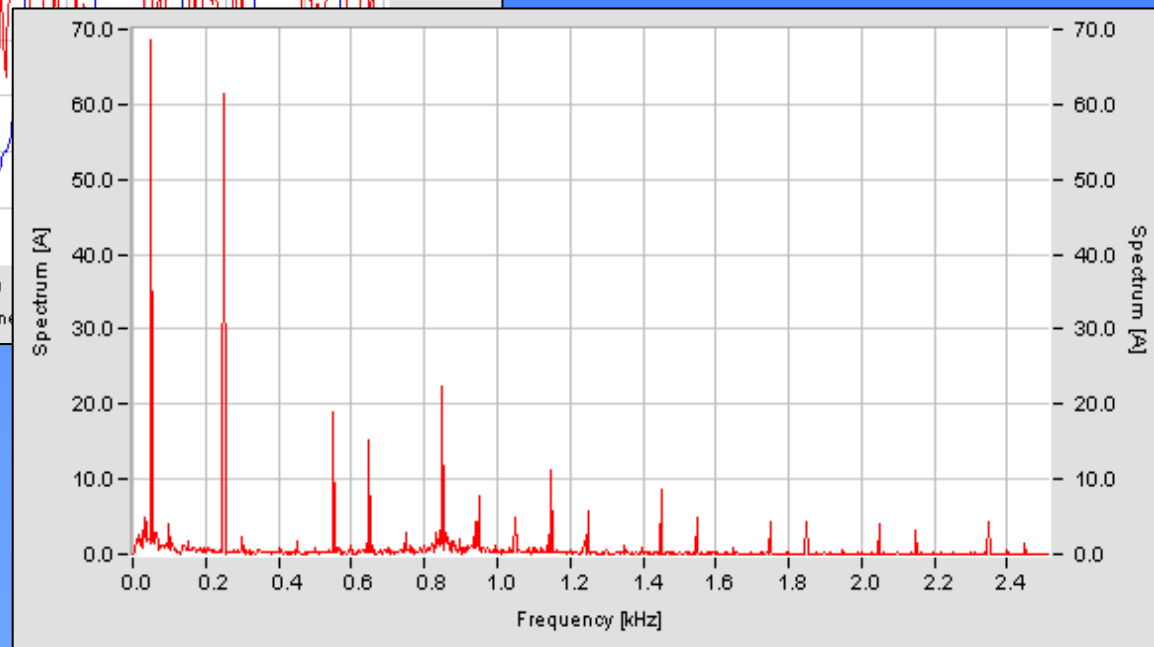
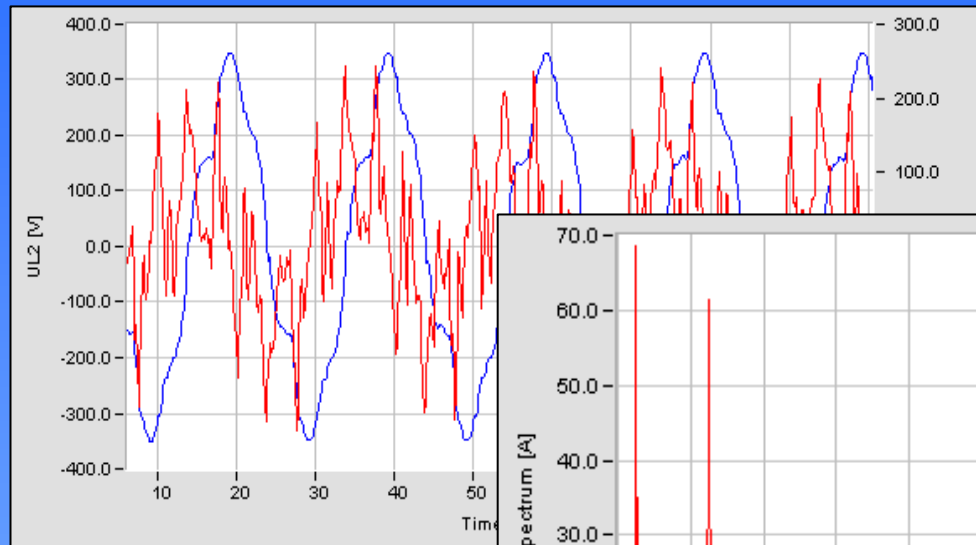
Napięcie i prąd baterii dla poszczególnych stopni



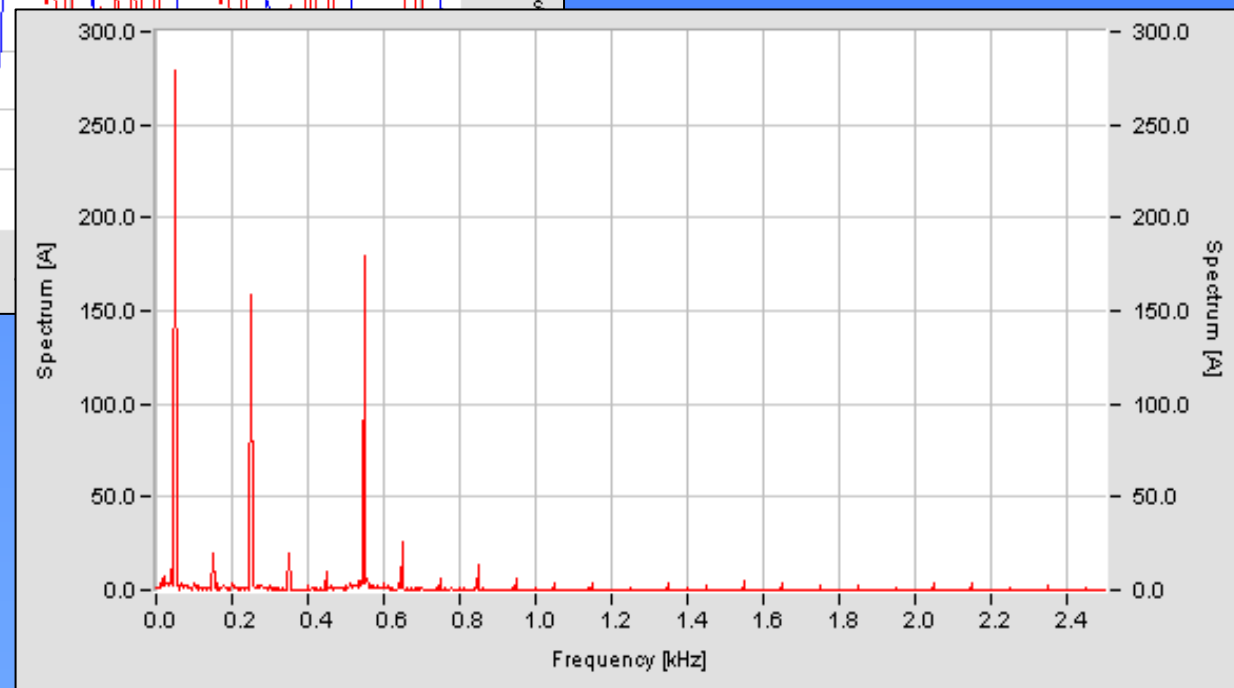
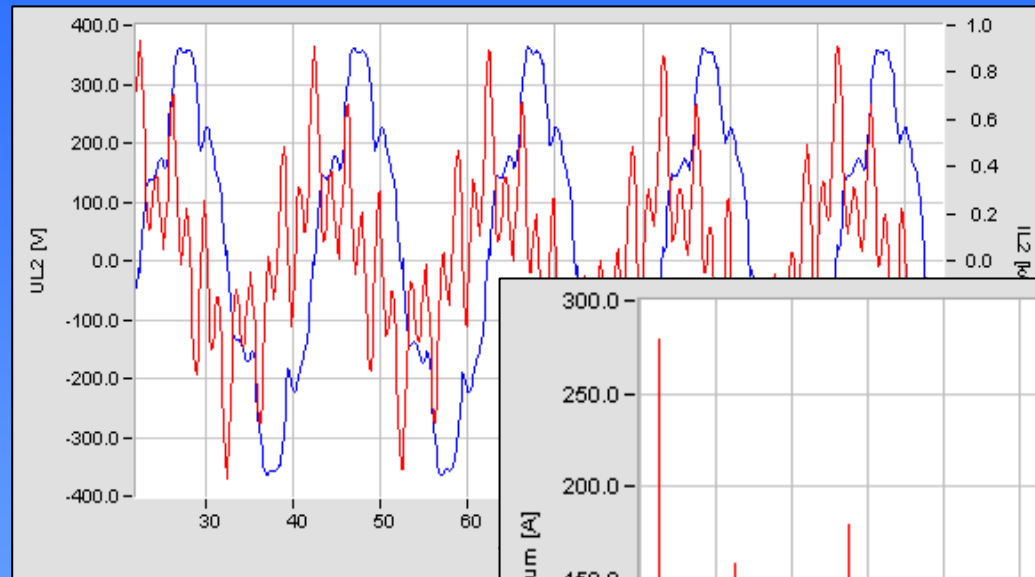
Stopień 1



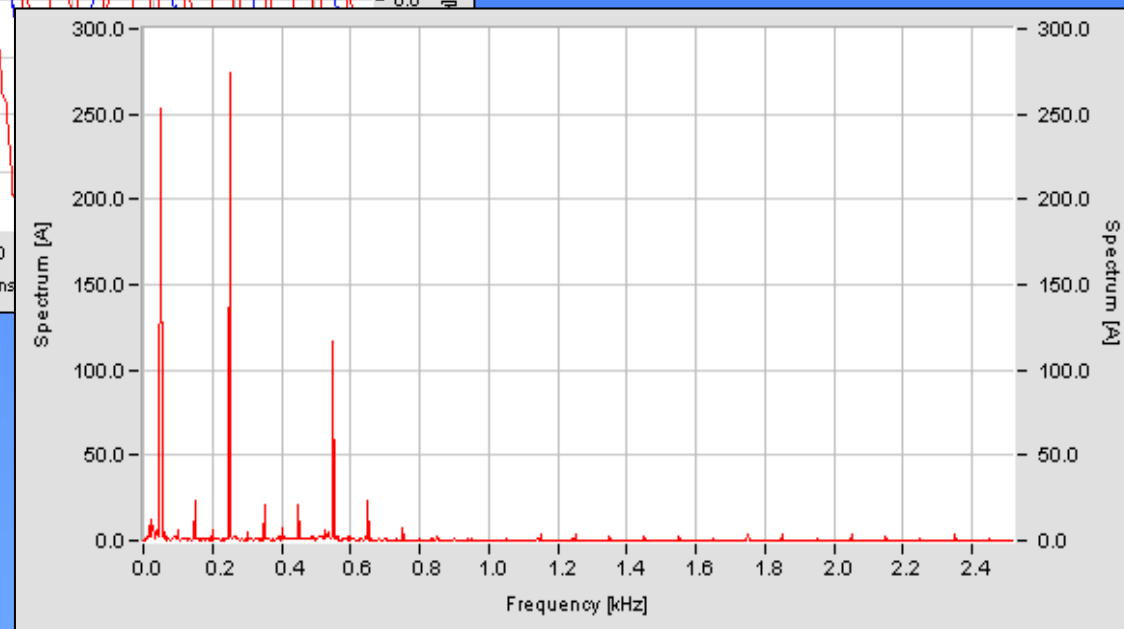
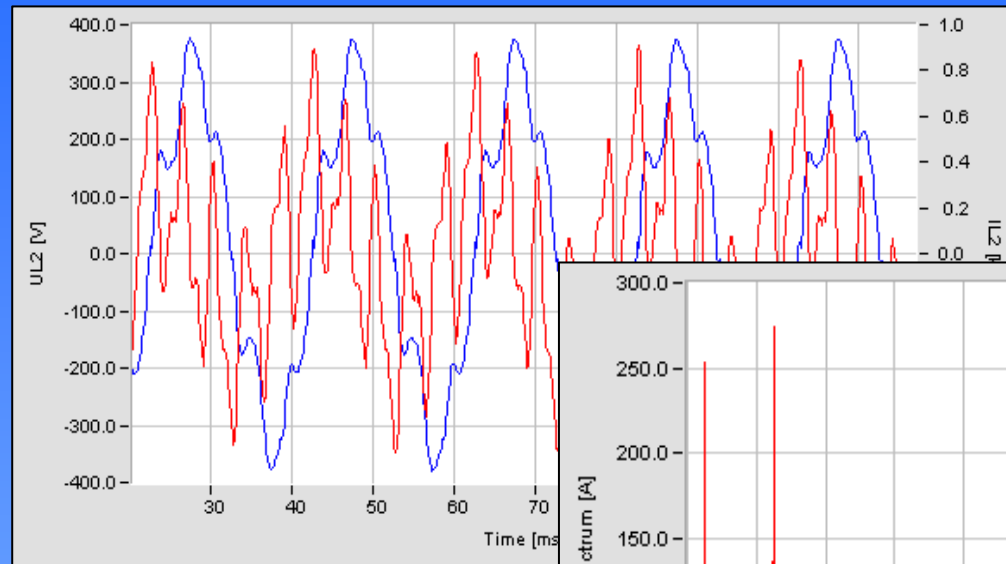
Stopień 2

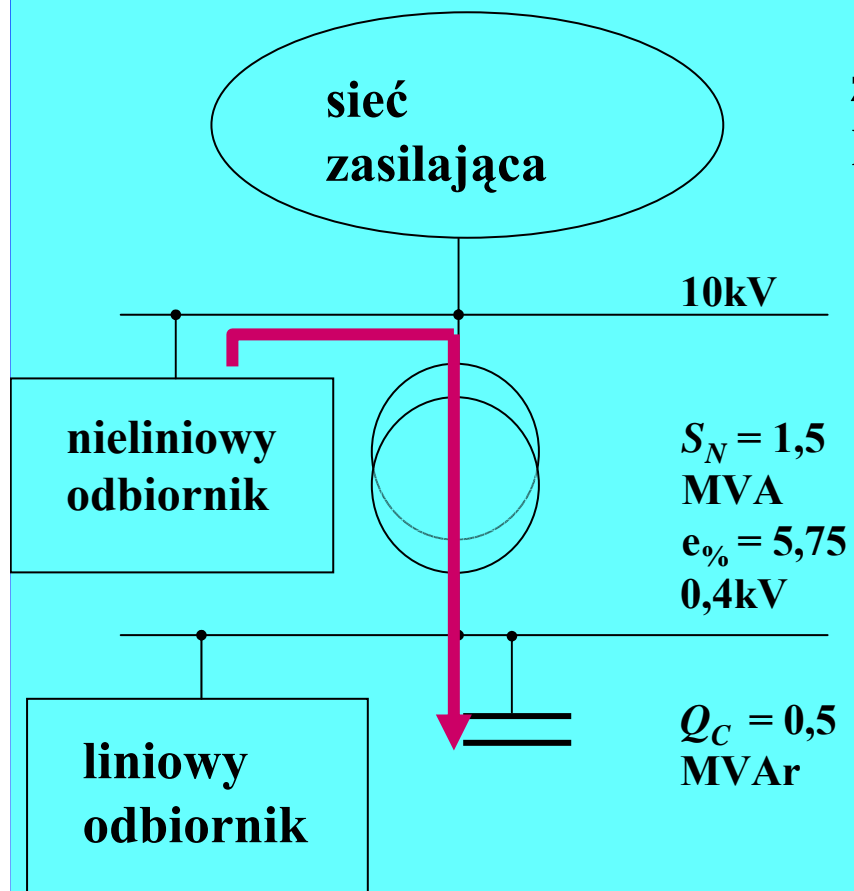


Stopień 4

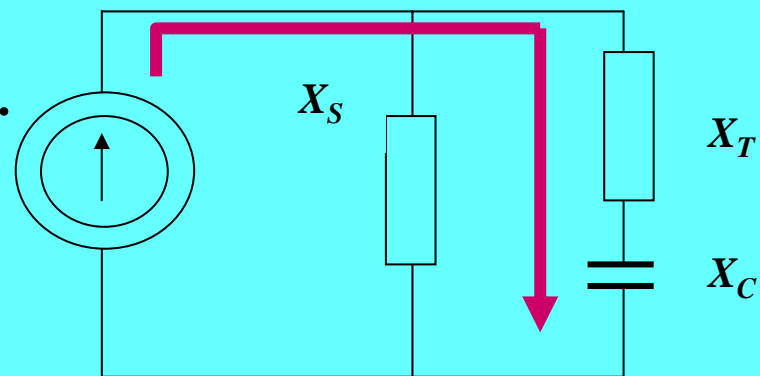


Stopień 5

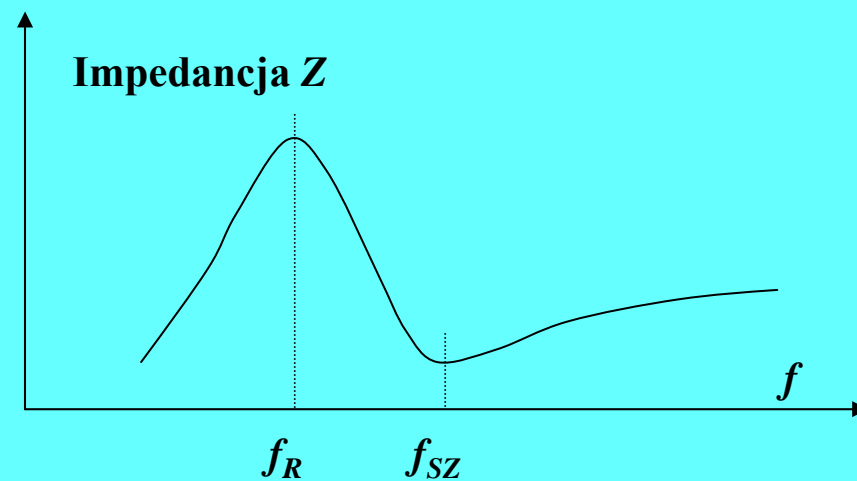




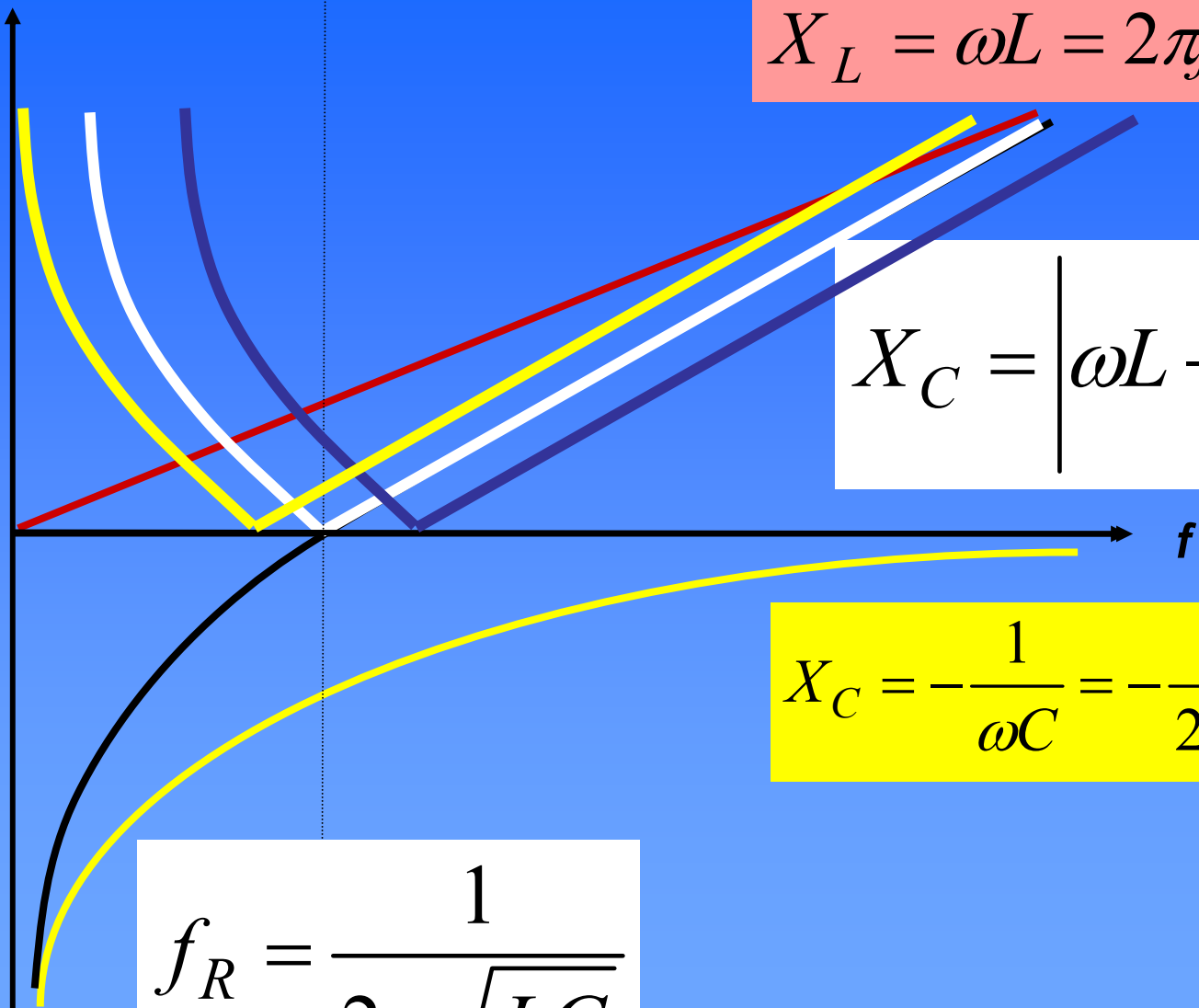
źródło harmonicz.



Impedan. Z



$|Z|$



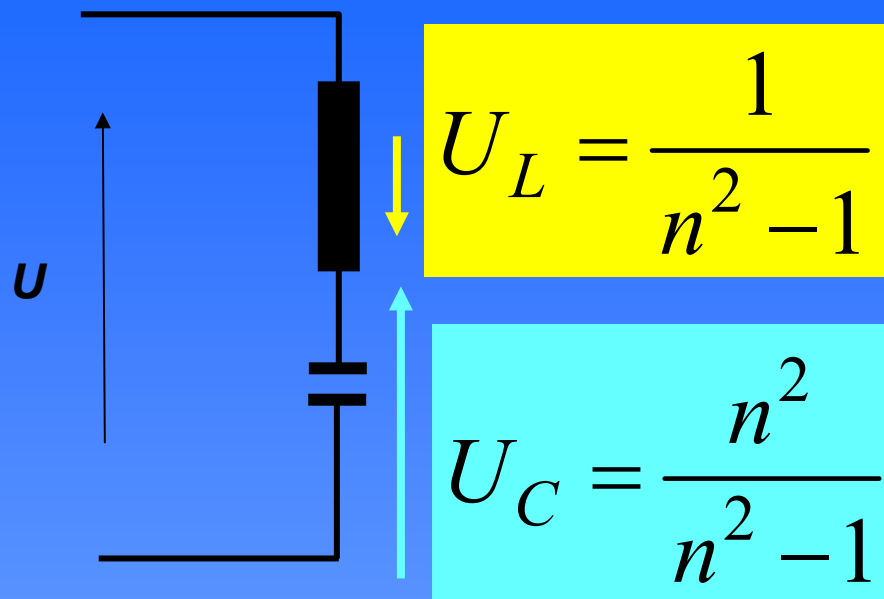
$$X_L = \omega L = 2\pi f L$$

$$X_C = \left| \omega L - \frac{1}{\omega C} \right|$$

$$X_C = -\frac{1}{\omega C} = -\frac{1}{2\pi f C}$$

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

Współczynnik tłumienia (dławik odstrajający)



$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

$$nf_1 = \frac{1}{2\pi\sqrt{LC}}$$

$$n = \frac{1}{2\pi f_1 \sqrt{LC}}$$

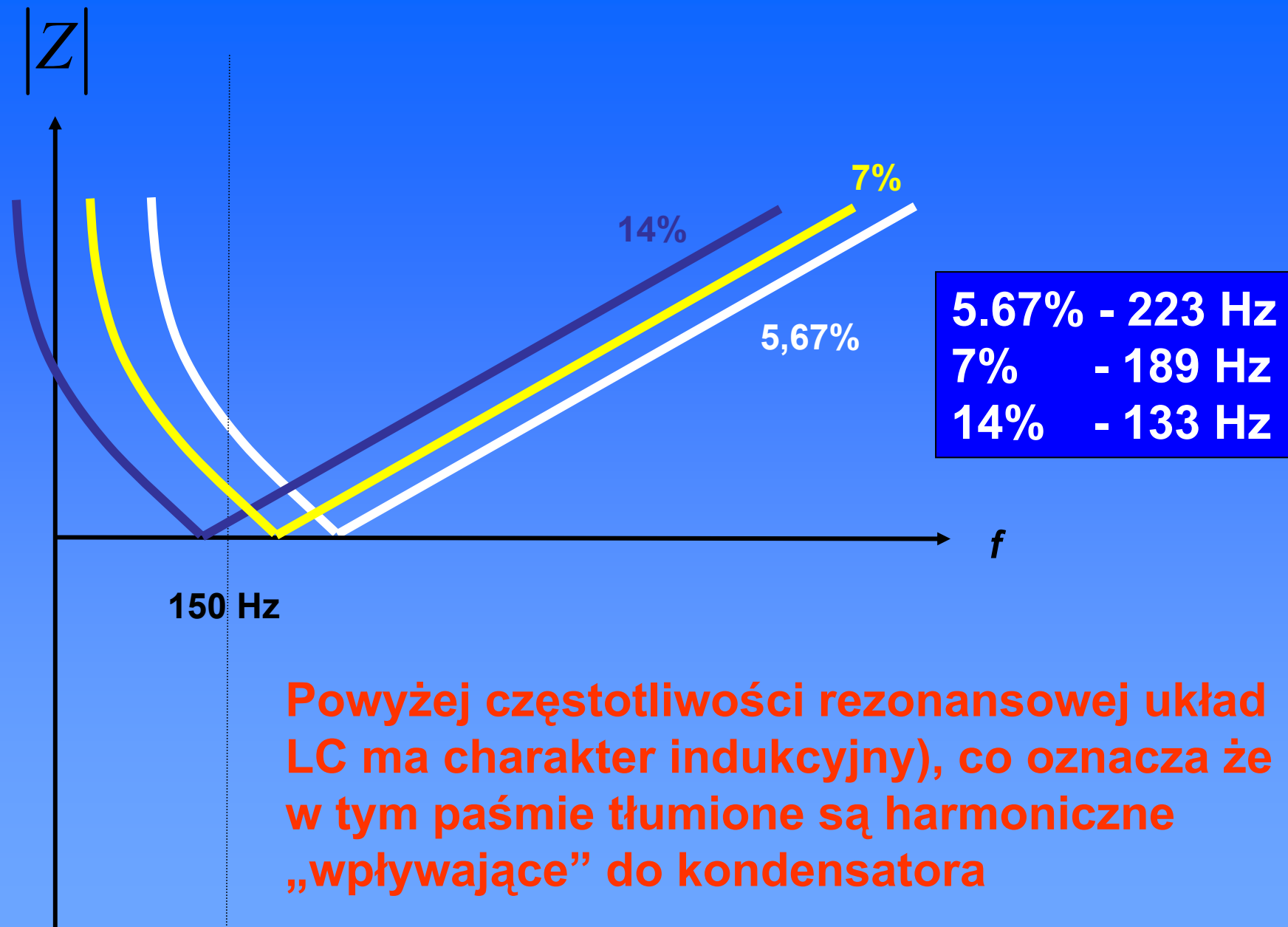
$$p\% = 100 \frac{U_L}{U_C} = \frac{100}{n^2} = 100 \left(\frac{f_{(1)}}{f_R} \right)^2$$

$$U_L \uparrow \Rightarrow L \uparrow \Rightarrow n_R \downarrow$$

5.67% - 223 Hz

7% - 189 Hz

14% - 133 Hz



Powyżej częstotliwości rezonansowej układ LC ma charakter indukcyjny), co oznacza że w tym paśmie tłumione są harmoniczne „wpływające” do kondensatora

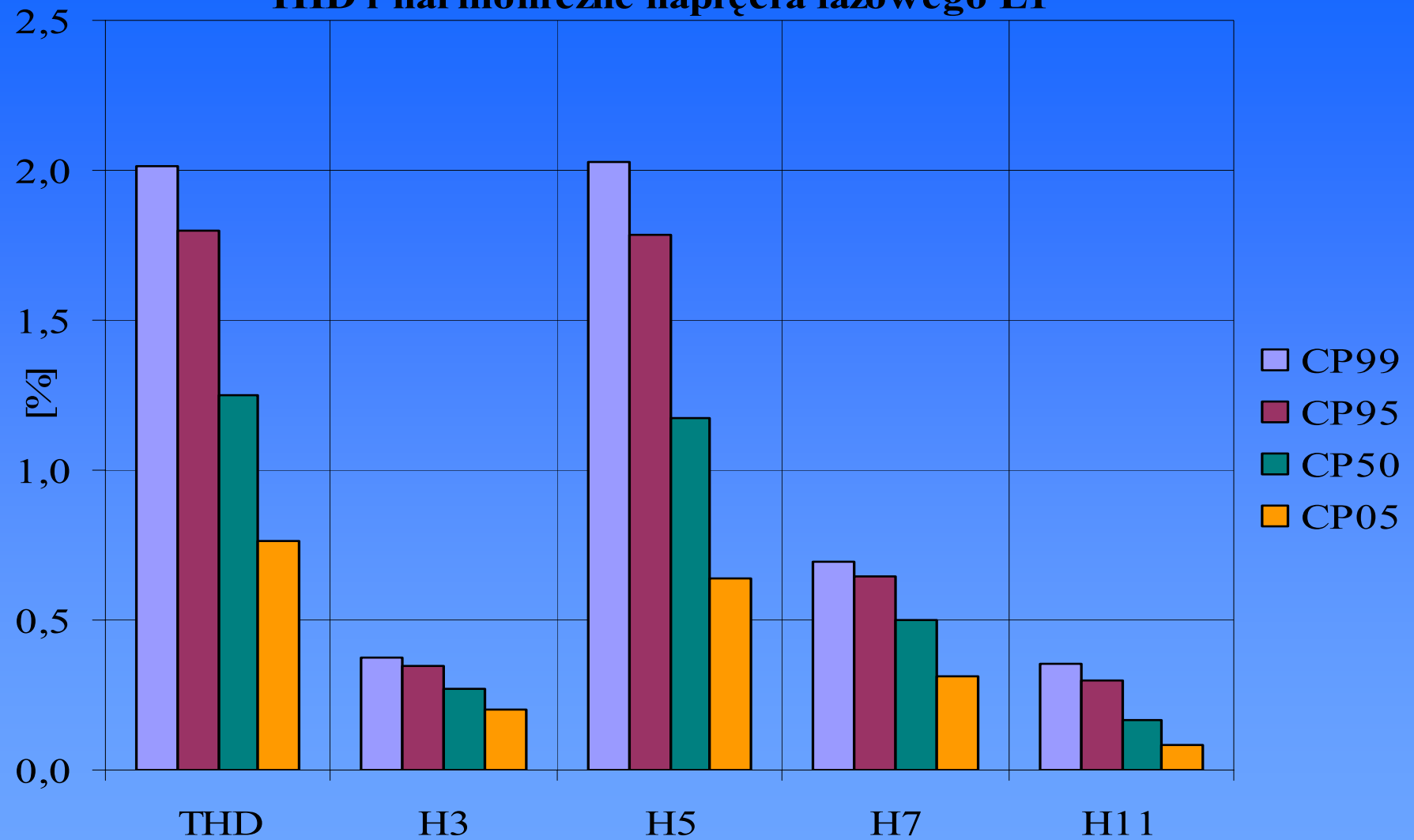
KONDENSATORY
FILTRACJA WYŻSZYCH
HARMONICZNYCH

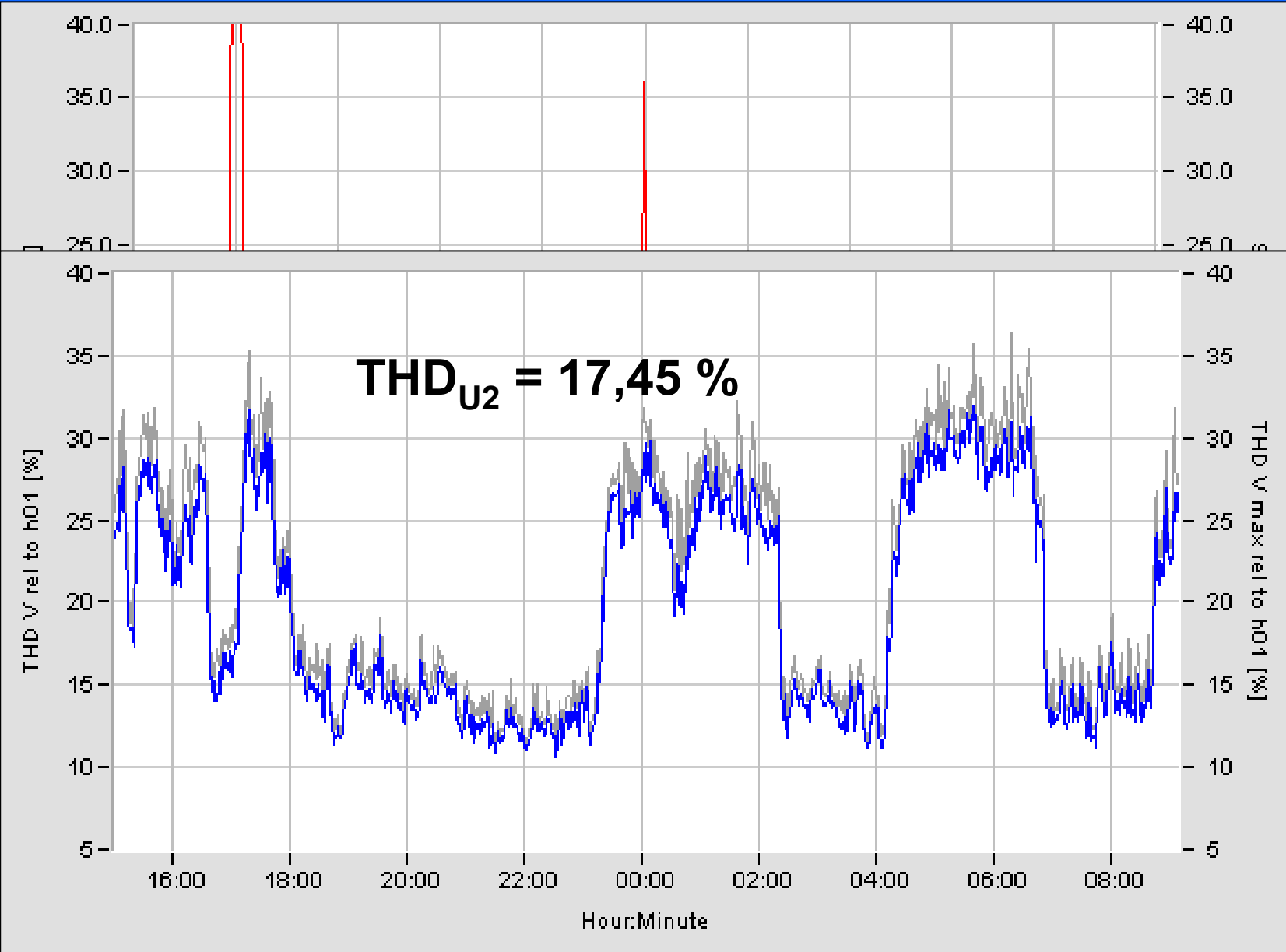
ODKSZTAŁCENIE PRZEBIEGÓW CZASOWYCH NAPIĘĆ I PRĄDÓW

$$\underline{U}_{(n)} = \frac{U_{(n)}}{U_{(1)}}$$

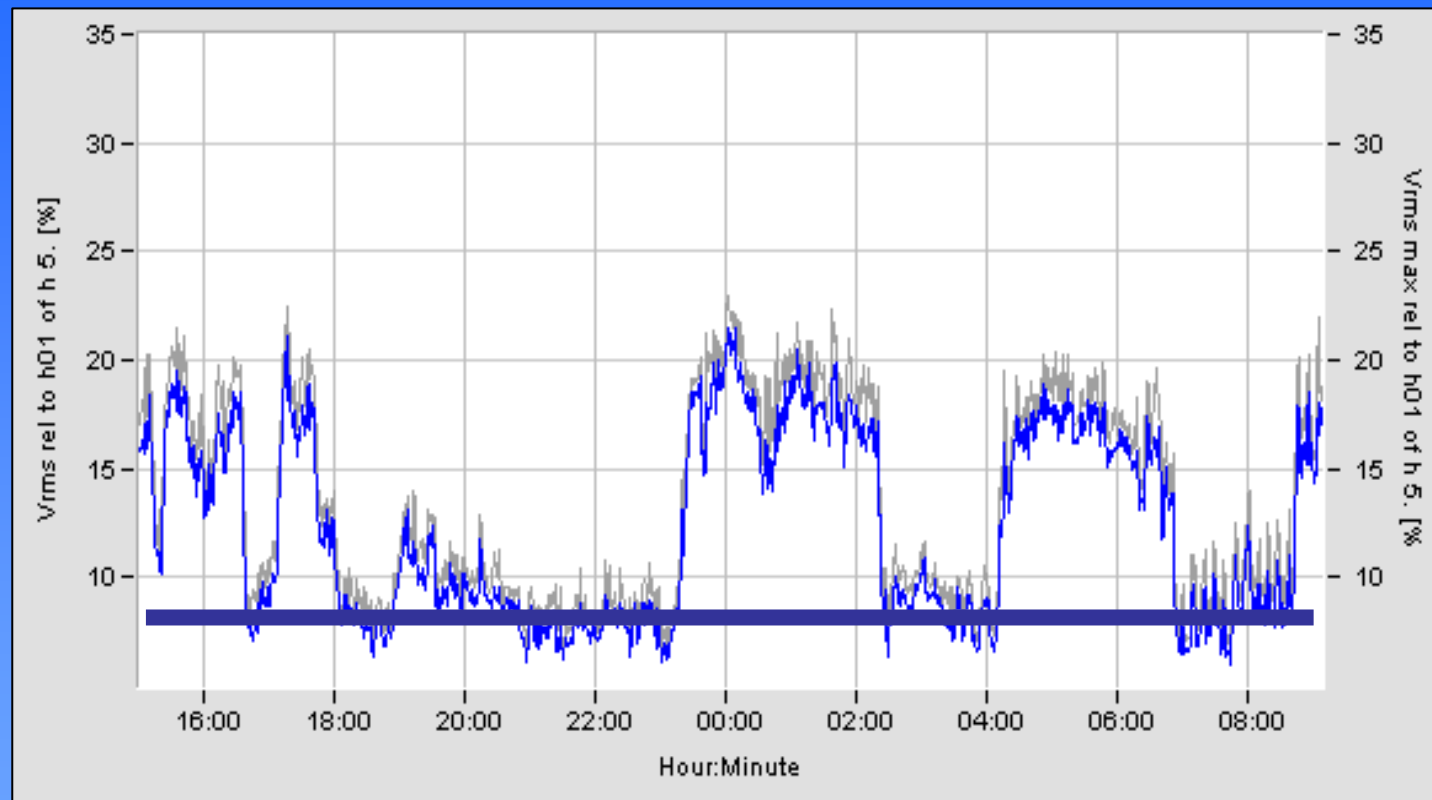
$$THD_U = \frac{\sqrt{\sum_{n=2}^{n_g} U_{(n)}^2}}{U_{(1)}} 100\%$$

THD i harmoniczne napięcia fazowego L1

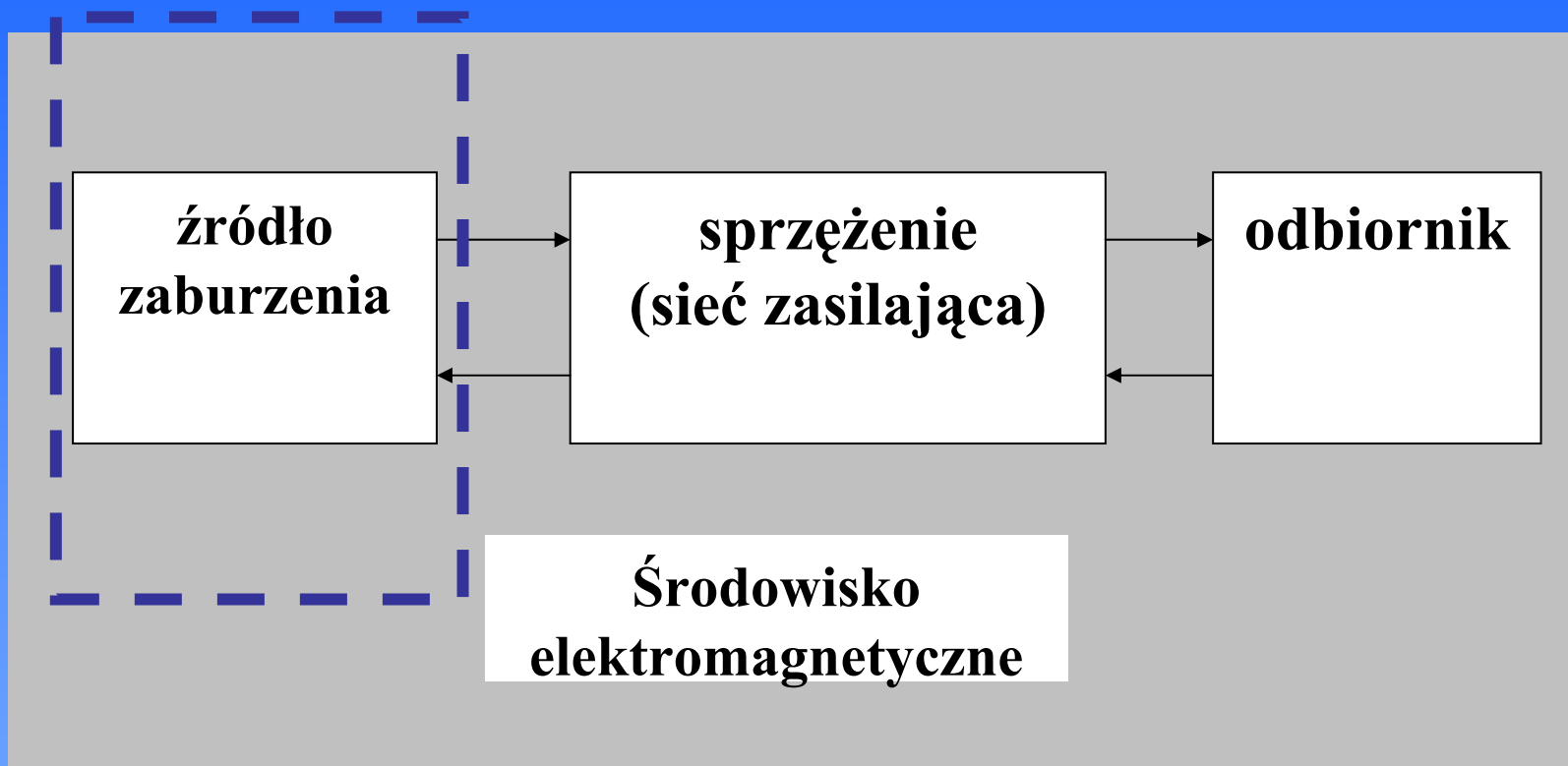




Harmoniczna 5

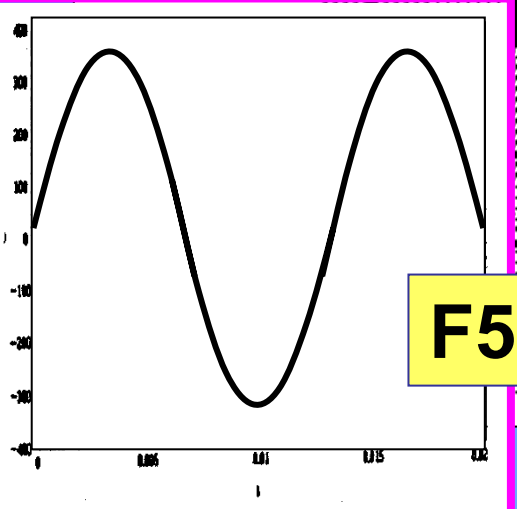
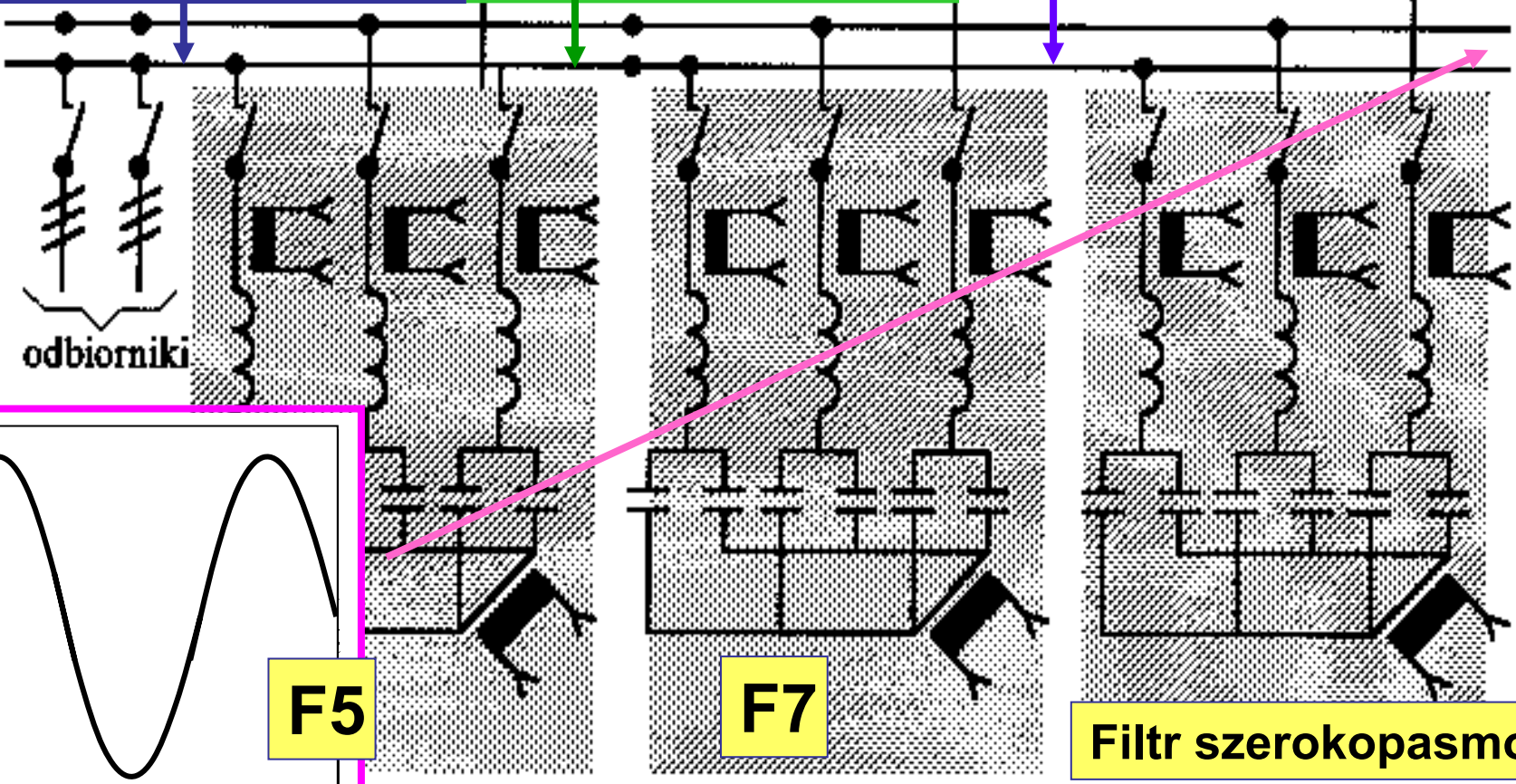
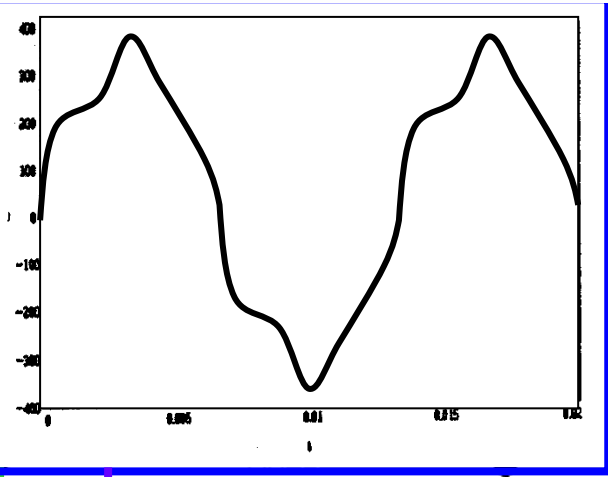
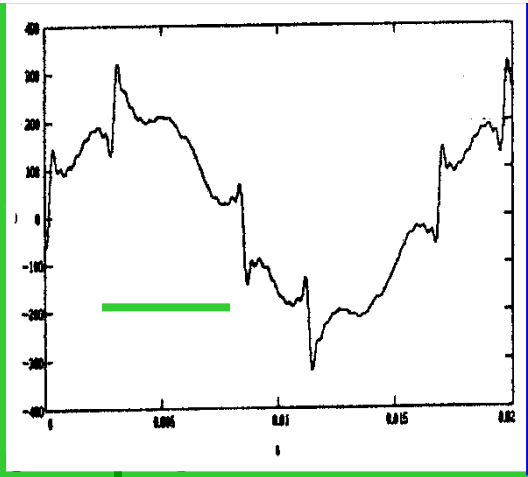
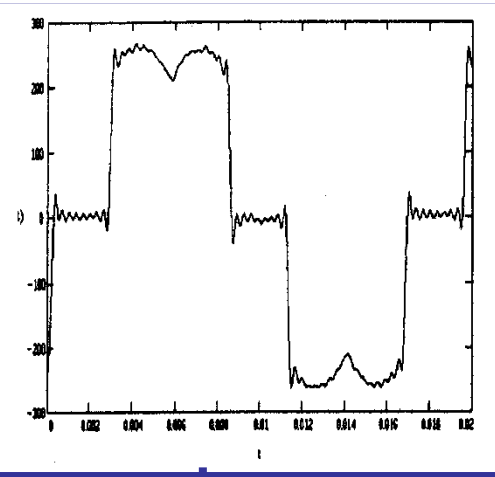


Sposoby rozwiązywania problemu harmonicznych



Funkcje filtru pasywnego

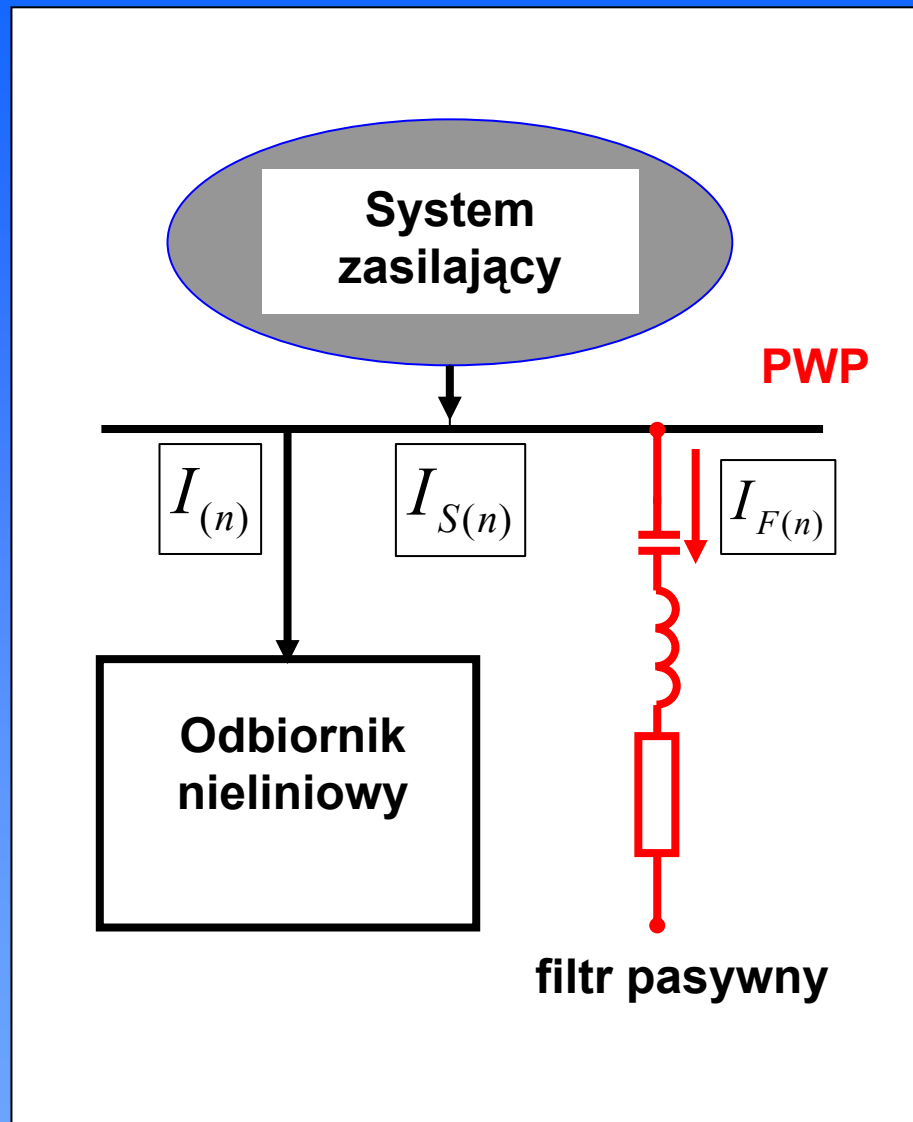
1. eliminacja harmoniczných prądu (napięcia)
2. kompensacja mocy biernej harmonicznej podstawowej



F5

F7

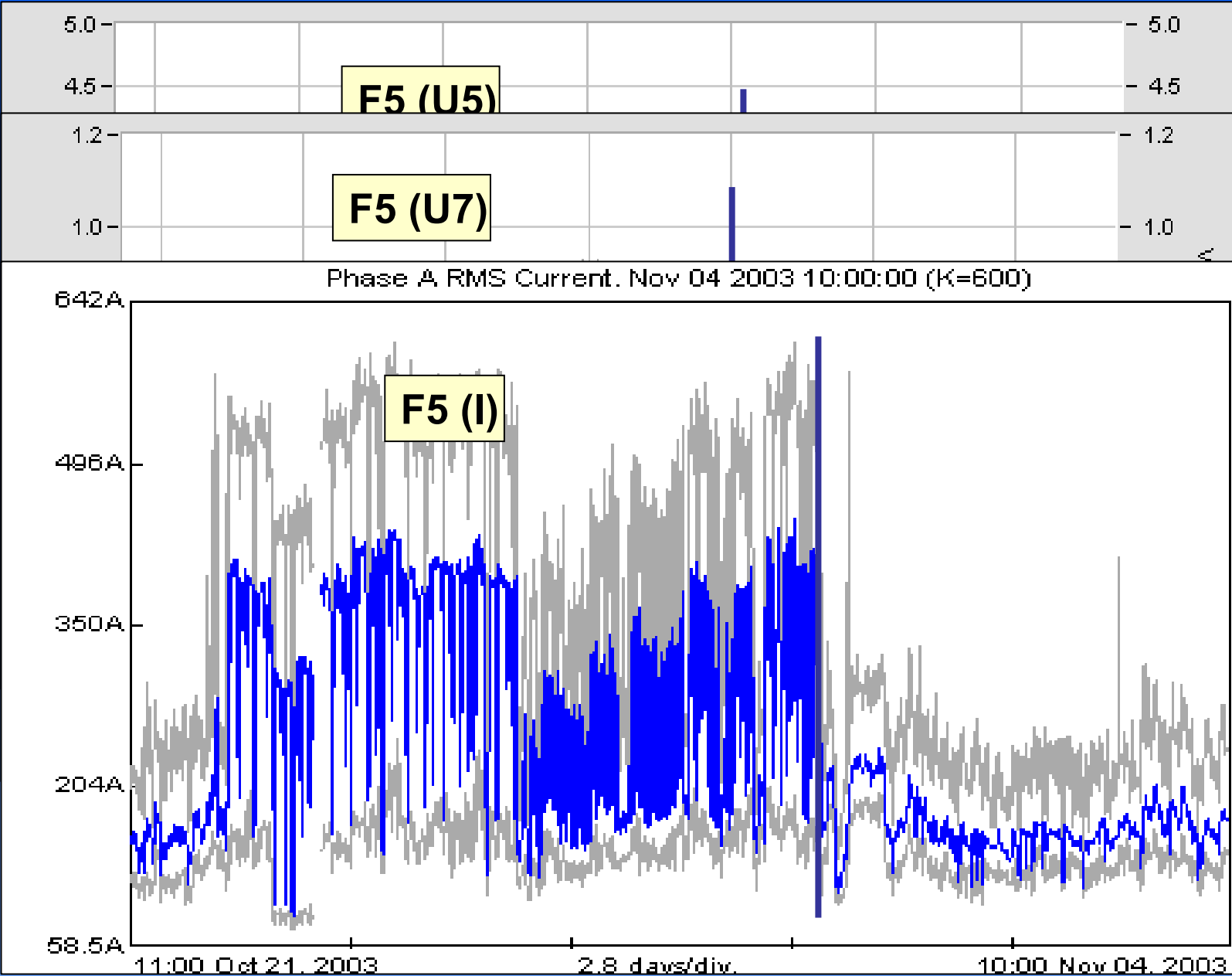
Filtr szerokopasmowy



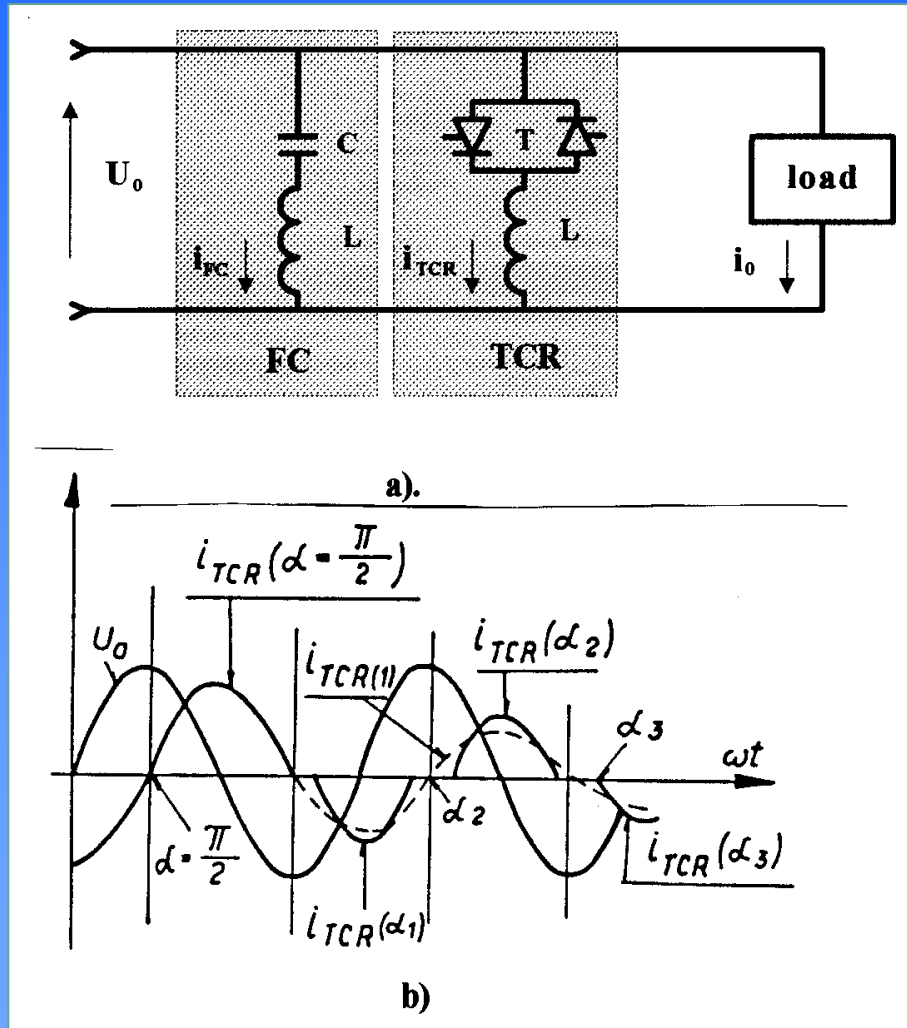
$$I_{S(n)} = \frac{Z_{F(n)}}{Z_{F(n)} + Z_{S(n)}} I_{(n)} = \rho_{S(n)} I_{(n)}$$

$$I_{F(n)} = \frac{Z_{S(n)}}{Z_{F(n)} + Z_{S(n)}} I_{(n)} = \rho_{F(n)} I_{(n)}$$

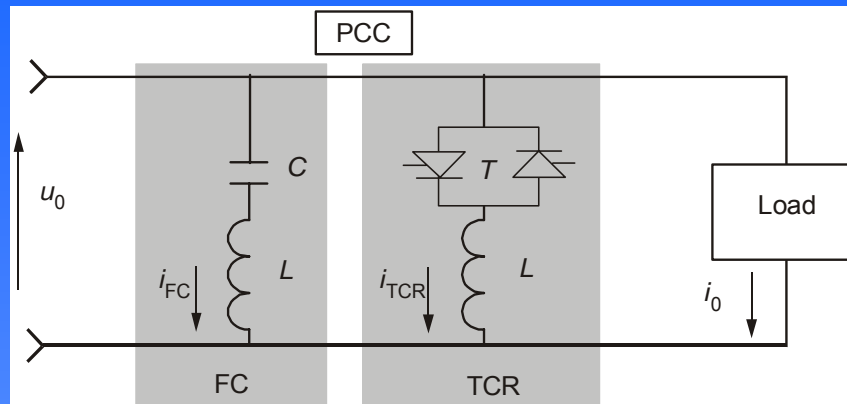
$$\rho_{S(n)} + \rho_{F(n)} = 1$$



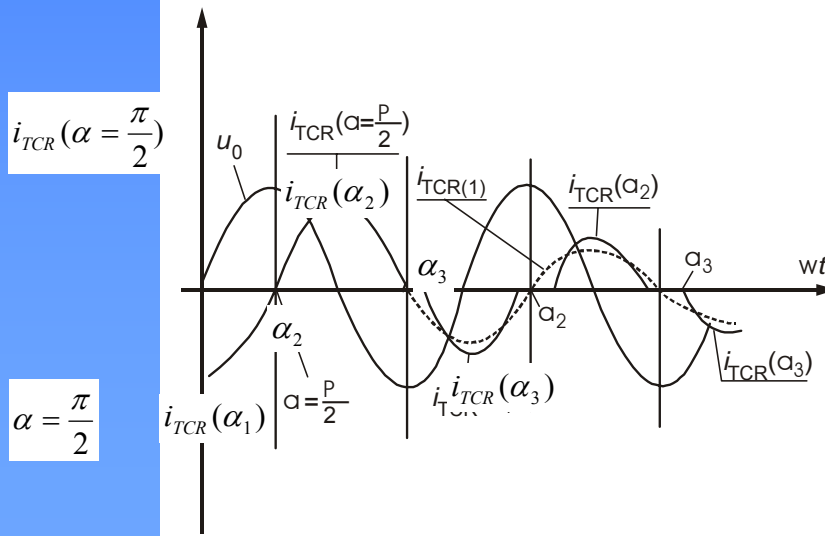
FC/TCR



FIXED CAPACITOR/THYRISTOR CONTROLLED REACTOR (FC/TCR)

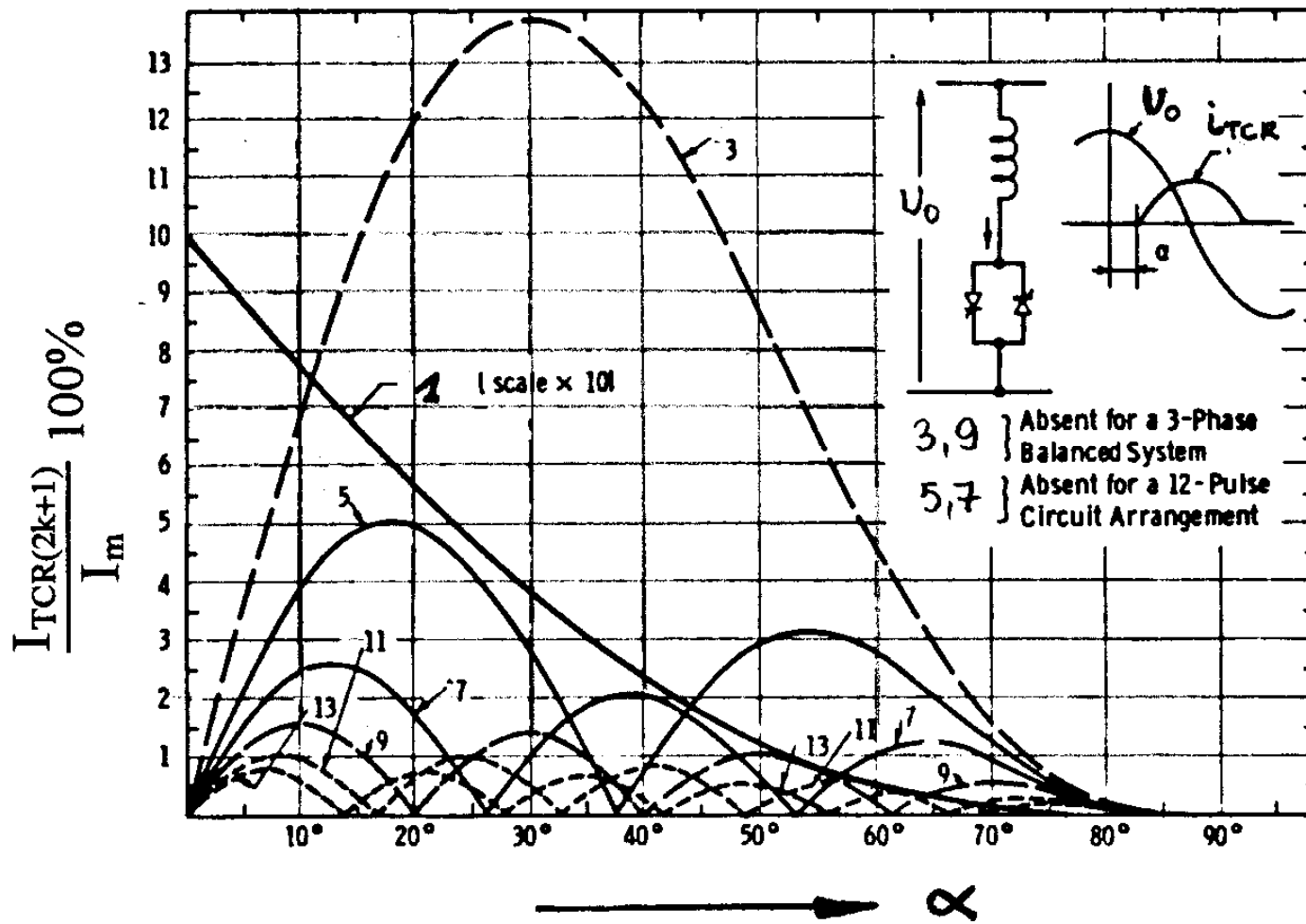


(a)

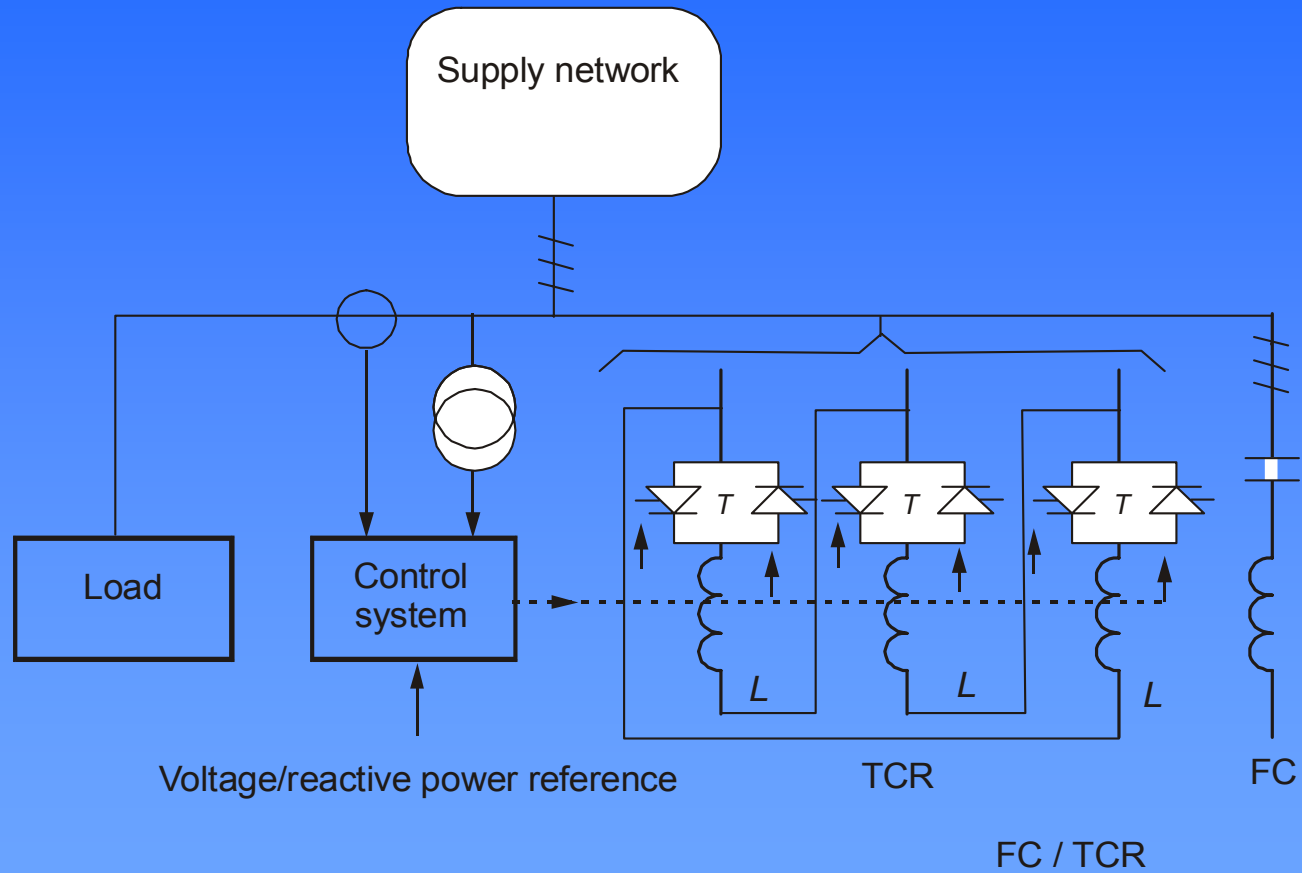


(b)

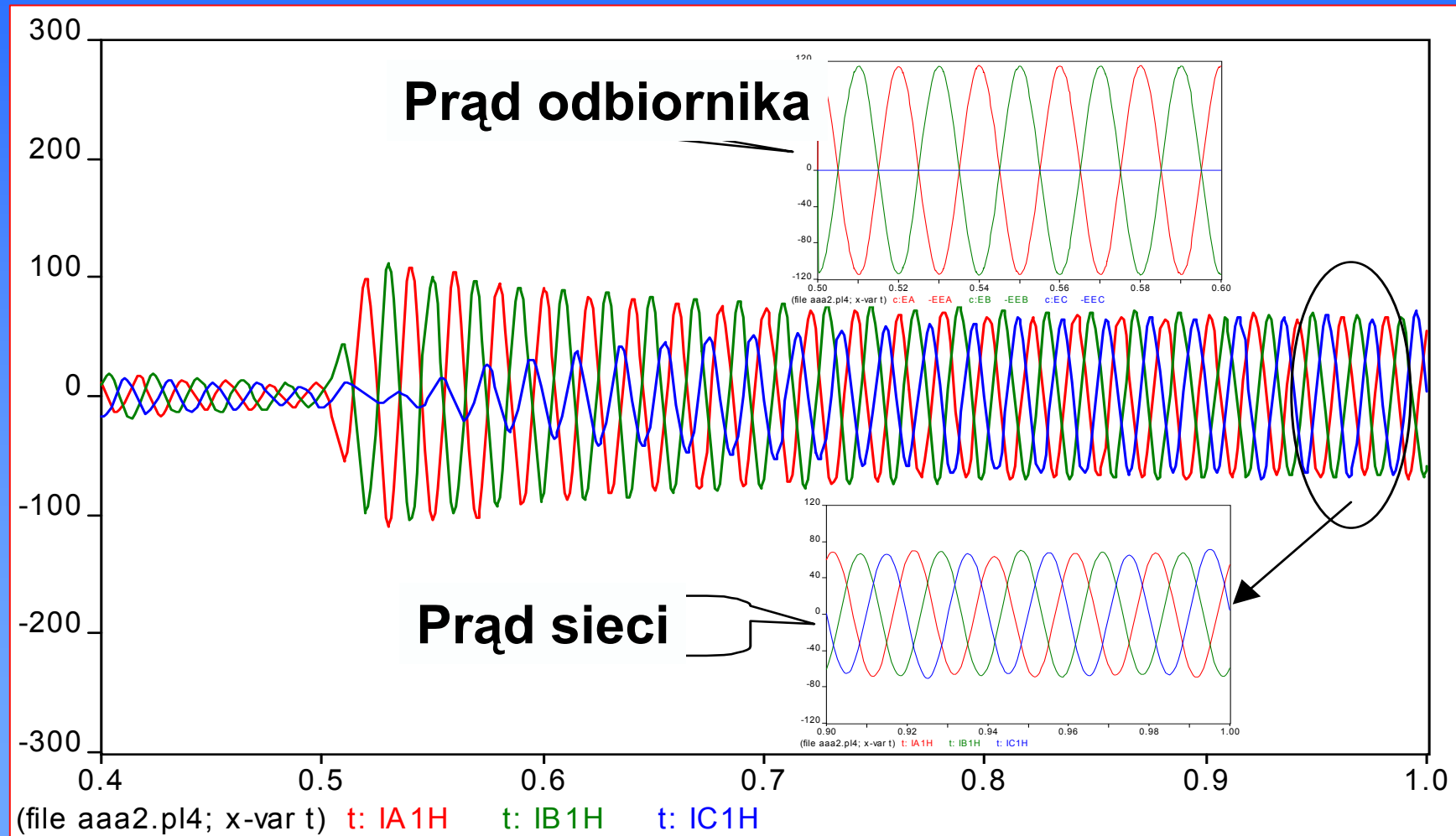
FC/TCR



FC/TCR

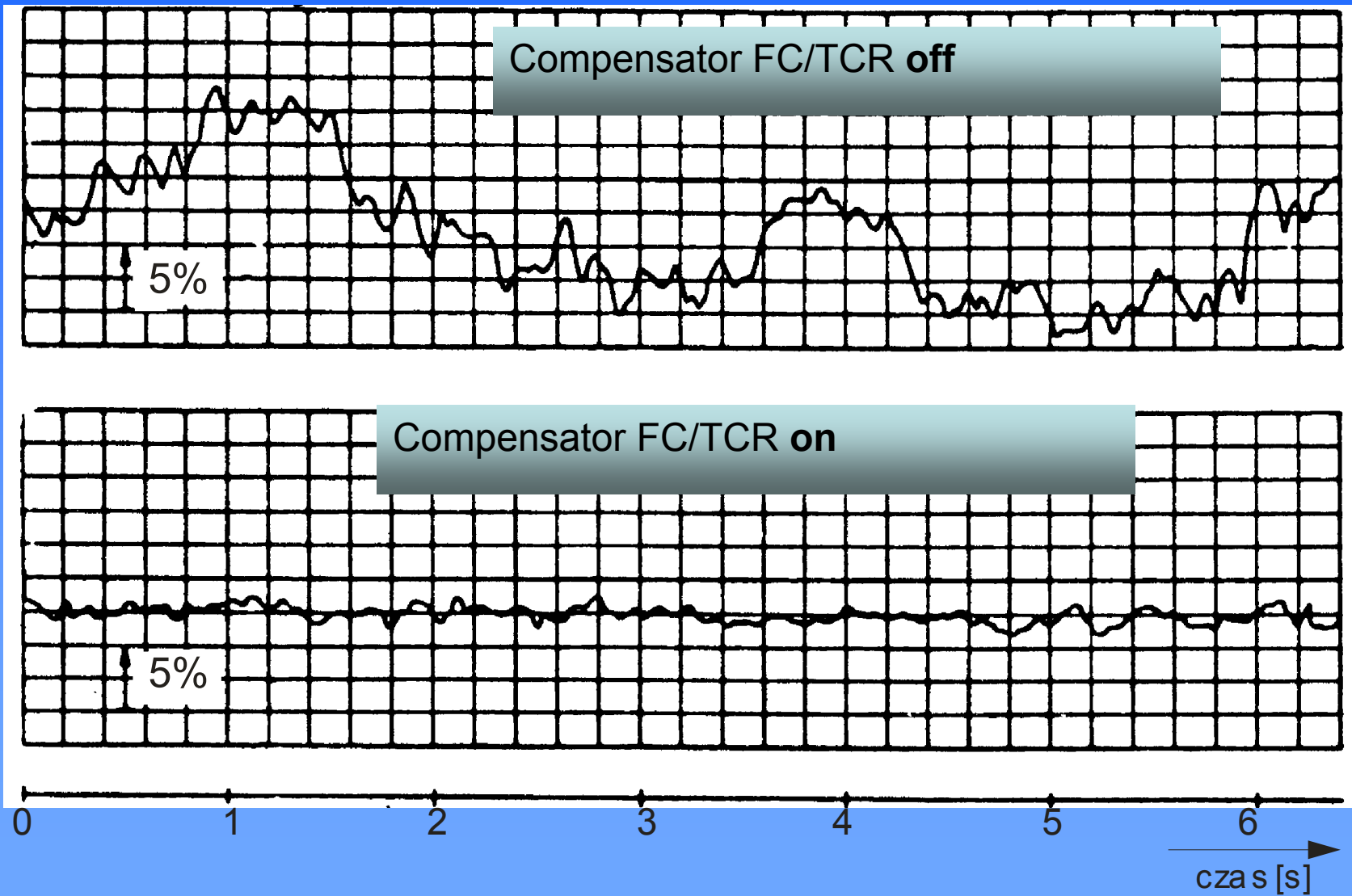


FC/TCR

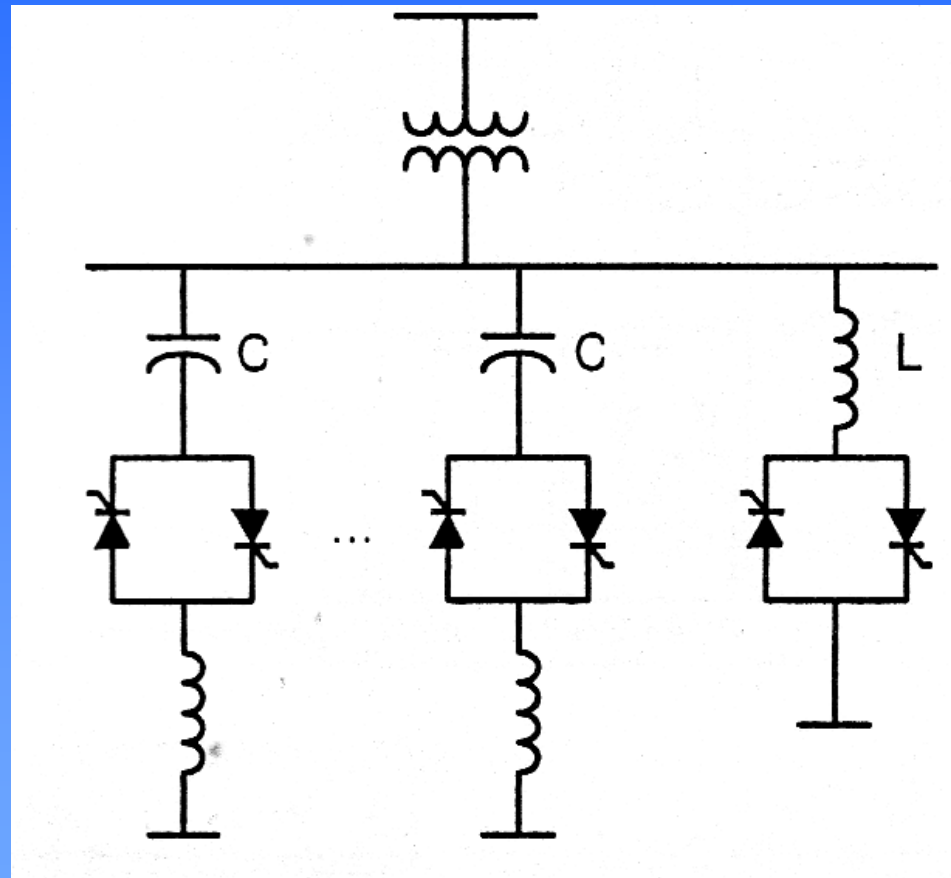


FC/TCR

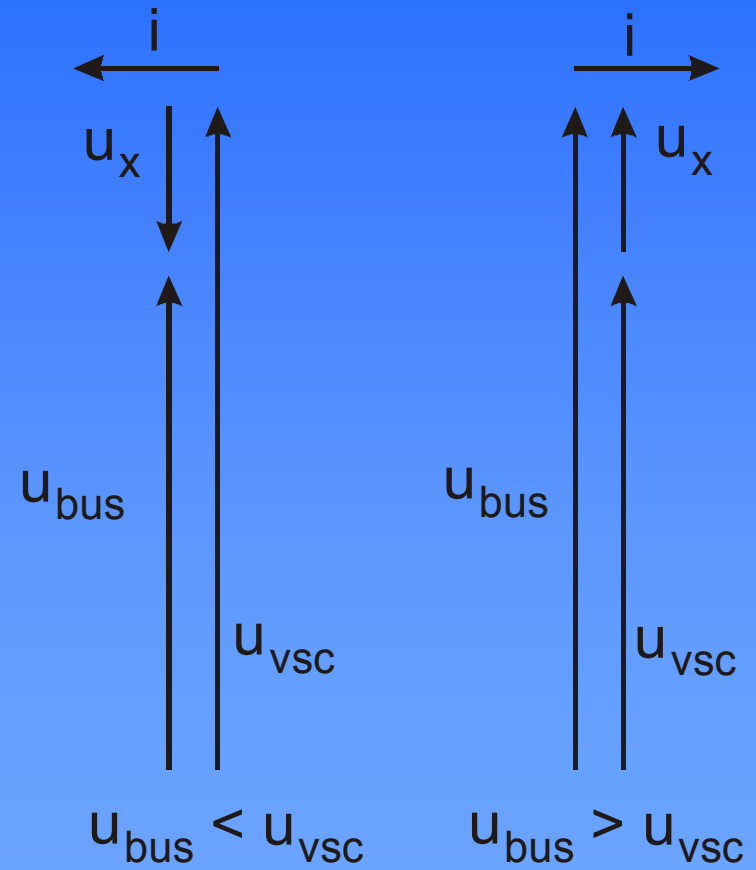
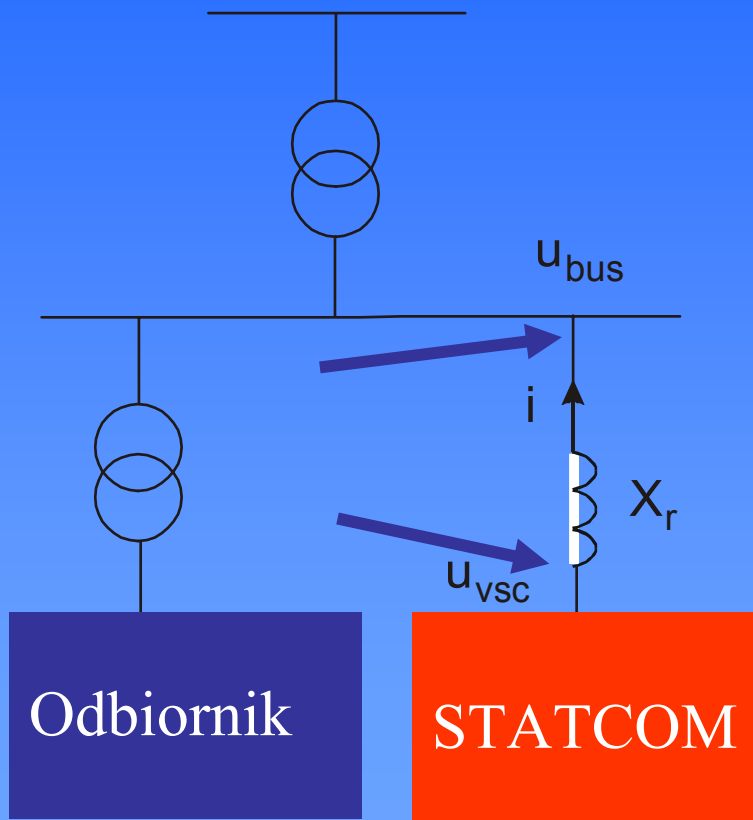
20 kV



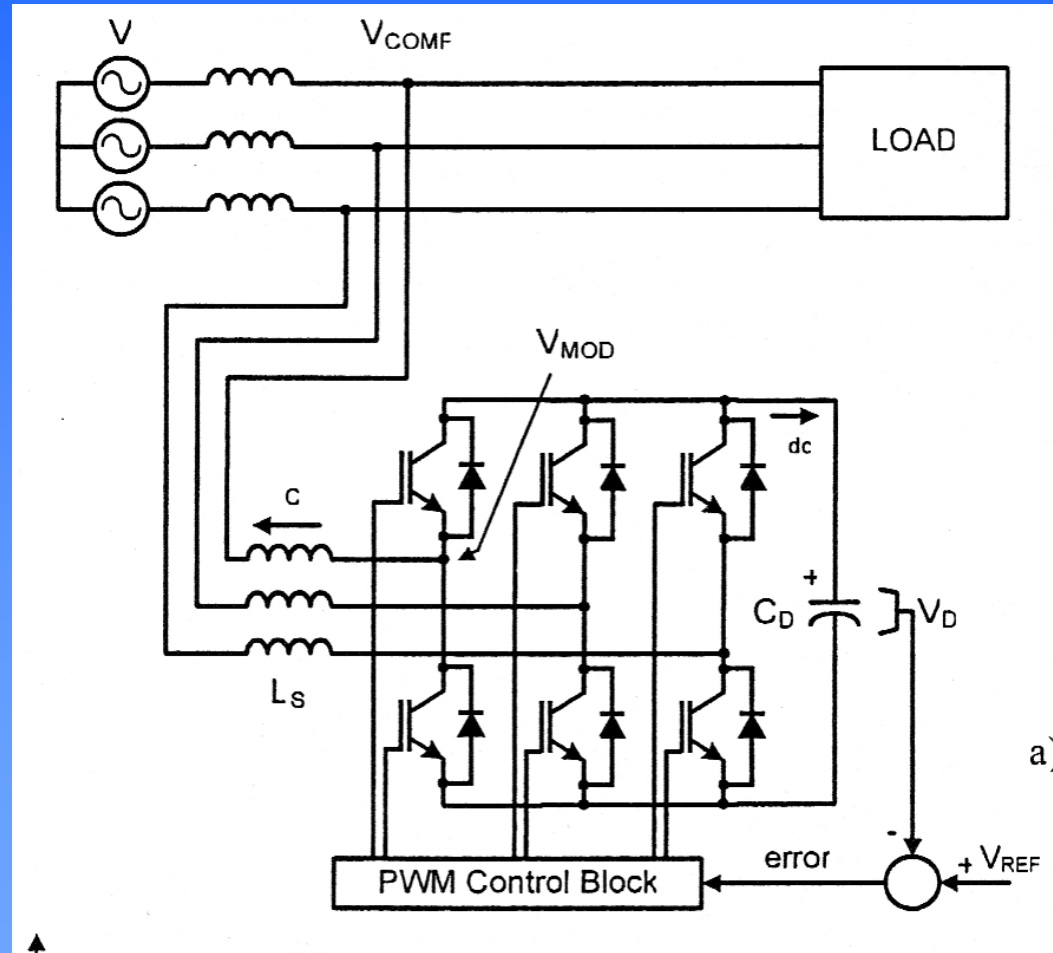
TSC/TCR



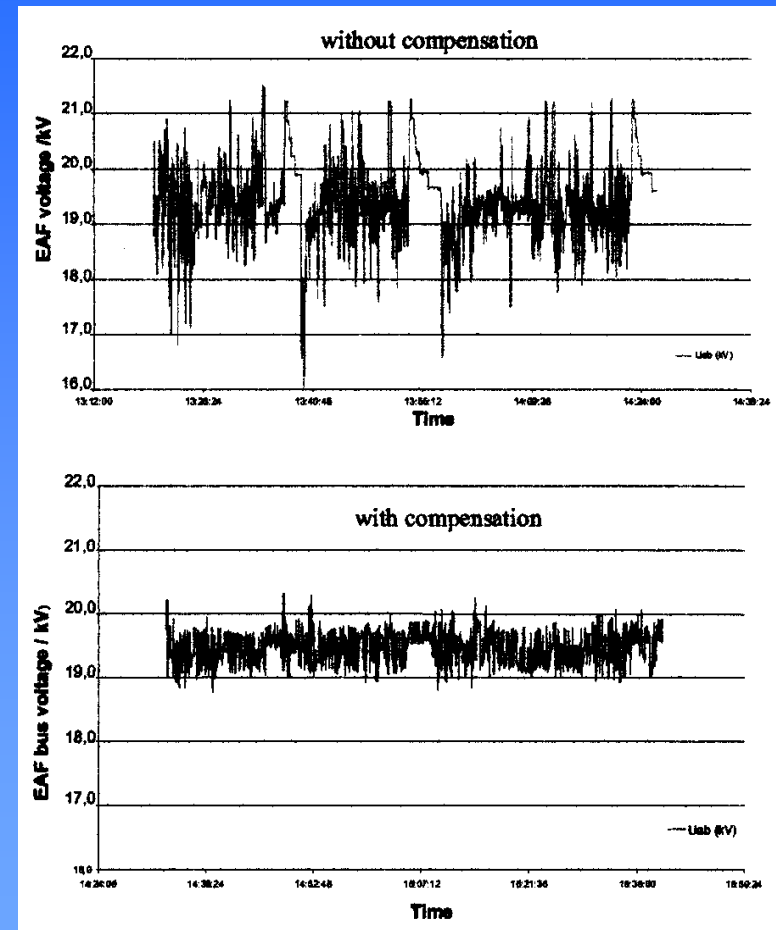
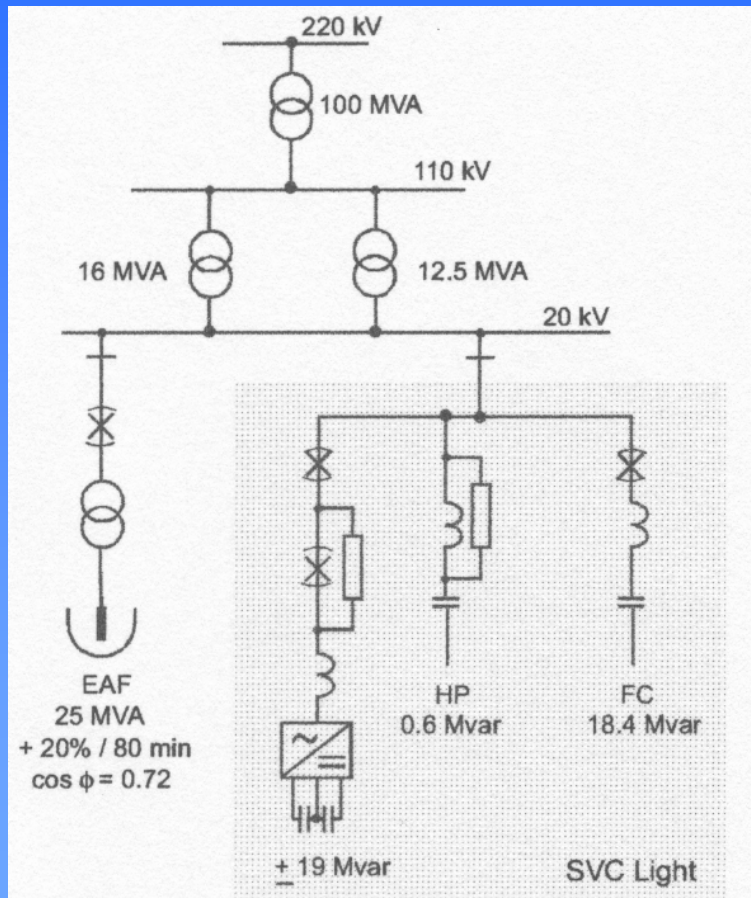
STATCOM



STATCOM



STATCOM



DZIĘKUJE ZA UWAGĘ . . .

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E-mail: hanzel@agh.edu.pl**