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مفهوم توان راکتیو

$$\begin{aligned} p(t) &= v(t)i(t) = 2VI \sin(\omega t) \sin(\omega t - \phi) \\ &= VI \cos \phi - VI \cos(2\omega t - \phi) \end{aligned}$$

$$p(t) = \underbrace{VI \cos \phi [1 - \cos(2\omega t)]}_{\text{(I)}} - \underbrace{VI \sin \phi \sin(2\omega t)}_{\text{(II)}}$$

$$p(t) = \underbrace{P[1 - \cos(2\omega t)]}_{\text{(I)}} - \underbrace{Q \sin(2\omega t)}_{\text{(II)}}$$

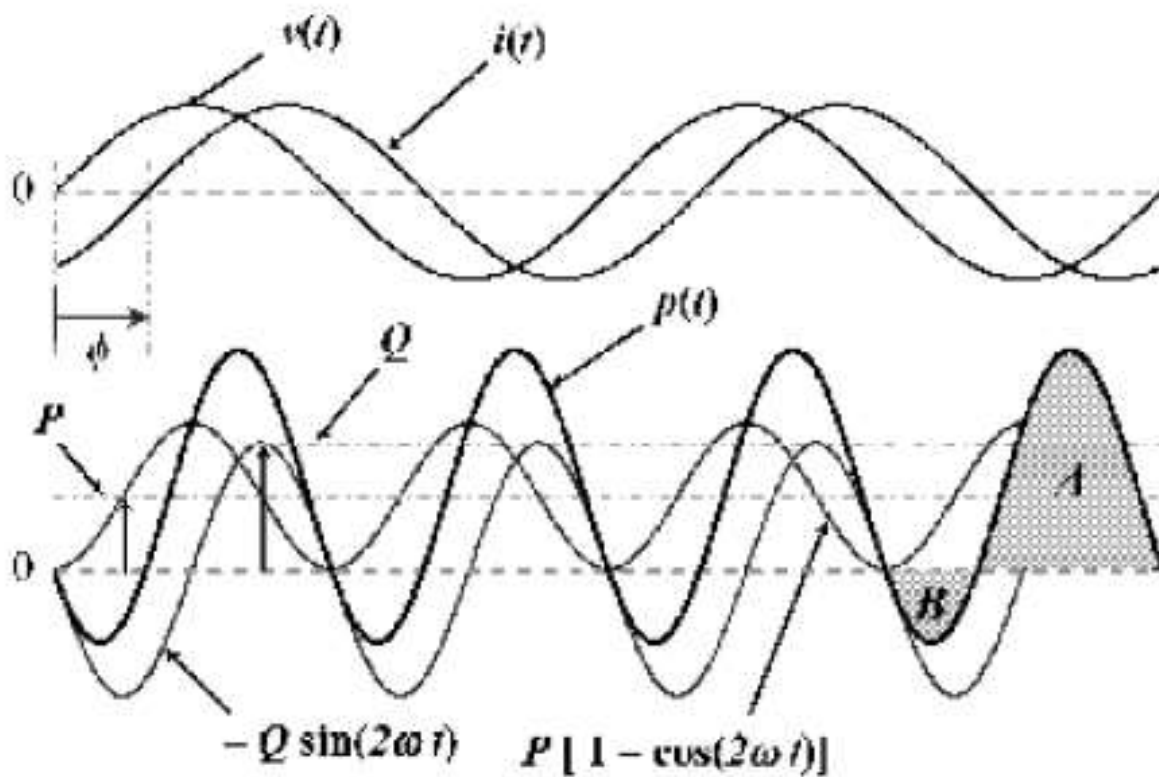
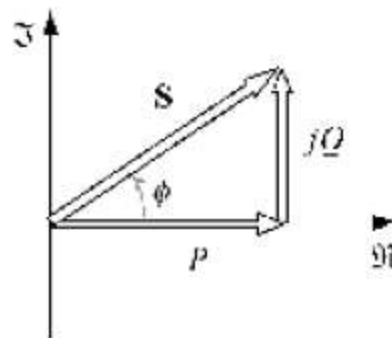


Figure 2-1. Conventional concepts of active and reactive power.

$$\mathbf{S} = \dot{V}i^* = (V \angle \theta_V)(I \angle -\theta_I) = \underbrace{VI \cos(\theta_V - \theta_I)}_P + j \underbrace{VI \sin(\theta_V - \theta_I)}_Q$$

$$|\mathbf{S}| = \sqrt{[VI \cos(\theta_V - \theta_I)]^2 + [VI \sin(\theta_V - \theta_I)]^2} = S = VI$$



$$\begin{cases} v_a(t) = \sqrt{2}V_+ \sin(\omega t + \phi_{V_+}) \\ v_b(t) = \sqrt{2}V_+ \sin\left(\omega t + \phi_{V_+} - \frac{2\pi}{3}\right) \\ v_c(t) = \sqrt{2}V_+ \sin\left(\omega t + \phi_{V_+} + \frac{2\pi}{3}\right) \end{cases}$$

$$\begin{cases} i_a(t) = \sqrt{2}I_+ \sin(\omega t + \phi_{I_+}) \\ i_b(t) = \sqrt{2}I_+ \sin\left(\omega t + \phi_{I_+} - \frac{2\pi}{3}\right) \\ i_c(t) = \sqrt{2}I_+ \sin\left(\omega t + \phi_{I_+} + \frac{2\pi}{3}\right) \end{cases}$$

$$p_{3\phi}(t) = v_a(t)i_a(t) + v_b(t)i_b(t) + v_c(t)i_c(t) = p_a(t) + p_b(t) + p_c(t)$$

$$p_{3\phi}(t) = V_+ I_+ \left[\cos(\phi_{V_+} - \phi_{I_+}) - \cos(2\omega t + \phi_{V_+} + \phi_{I_+}) + \right. \\ \left. + \cos(\phi_{V_+} - \phi_{I_+}) - \cos\left(2\omega t + \phi_{V_+} + \phi_{I_+} + \frac{2\pi}{3}\right) + \right. \\ \left. + \cos(\phi_{V_+} - \phi_{I_+}) - \cos\left(2\omega t + \phi_{V_+} + \phi_{I_+} - \frac{2\pi}{3}\right) \right]$$

$$p_{3\phi}(t) = 3V_+ I_+ \cos(\phi_{V_+} - \phi_{I_+}) = 3P$$

$$P_{3\phi} = 3P = 3V_+ I_+ \cos(\phi_{V_+} - \phi_{I_+})$$

$$p(t) = \underbrace{P[1 - \cos(2\omega t)]}_{\text{(I)}} - \underbrace{Q \sin(2\omega t)}_{\text{(II)}}$$

$$\begin{aligned} S_{3\phi} &= 3\dot{V}_+ i_+^* = 3V_+ \angle \phi_{V_+} I_+ \angle -\phi_{I_+} \\ &= 3V_+ I_+ \underbrace{\cos(\phi_{V_+} - \phi_{I_+})}_{P_{3\phi}} + j \underbrace{3V_+ I_+ \sin(\phi_{V_+} - \phi_{I_+})}_{Q_{3\phi}} \end{aligned}$$

$P_{3\phi}$

$Q_{3\phi}$

مدیریت ولتاژ به منظور

Voltage Optimization

بررسی صورت گرفته توسط [EPRI] نشان می دهد که مقدار توان بارهای مختلف تابعی از دمای هوا ، فرکانس ، ولتاژ اعمال شده به آنهاست. وابستگی بارها به ولتاژ ، فرکانس ، دما و گشتاور بار (در موتورها) را معمولا به سه روش رگرسیون چند جمله ای، رگرسیون نمایی و رگرسیون ترکیبی مدل می کنند

$P = 1.0 + 0.3769\Delta V + 2.003\Delta V^2$ $Q = 0$	آبگرمکن
$P = 1.0 + 1.3958\Delta V + 9.881\Delta V^2 + 84.72\Delta V^3 + 293\Delta V^4$ $Q = 1.2507 + 4.387\Delta V + 23.801\Delta V^2 + 1540\Delta V^3 + 555\Delta V^4$	یخچال
$P = 1.0 + 1.3286\Delta V + 12.616\Delta V^2 + 133.6\Delta V^3 + 380\Delta V^4$ $Q = 1.3810 + 4.6702\Delta V + 27.276\Delta V^2 + 293\Delta V^3 + 995\Delta V^4$	فریزر
$P = 1.0 + 1.2786\Delta V + 3.099\Delta V^2 + 5.939\Delta V^3$ $Q = 1.6388 + 4.5733\Delta V + 12.948\Delta V^2 + 55.677\Delta V^3$	ماشین ظرفشویی و لباسشویی
$P = 1.0 + 1.2471\Delta V + 0.562\Delta V^2$ $Q = 0.2431 + 0.9830\Delta V + 1.647\Delta V^2$	تلویزیون
$P = 1.0 + 1.5209\Delta V + 0.223\Delta V^2$ $Q = 0$	لامپ التهایبی
$P = 1.0 + 0.6534\Delta V - 1.65\Delta V^2$ $Q = -0.1535 - 0.0403\Delta V + 2.734\Delta V^2$	لامپ فلورسنت
$P = 1.0 + 0.1309\Delta V + 0.504\Delta V^2$ $Q = -0.2524 + 2.3329\Delta V + 7.811\Delta V^2$	لامپ بخار جیوه
$P = 1.0 + 0.3409\Delta V - 2.389\Delta V^2$ $Q = 0.060 + 2.2173\Delta V + 7.620\Delta V^2$	لامپ بخار سدیم

$$P = P_0 \left[\frac{V}{V_0} \right]^{\alpha_v} \quad (2)$$

$$Q = Q_0 \left[\frac{V}{V_0} \right]^{\beta_v} \quad (3)$$

که در رابطه فوق :

P : توان تغییر یافته (با تغییر ولتاژ) مولفه بار؛

P_0 : توان نامی مولفه بار؛

α_v : نمای تابع رگرسیون توان آکیو؛

Q : توان تغییر یافته (با تغییر ولتاژ) مولفه بار؛

Q_0 : توان نامی مولفه بار؛

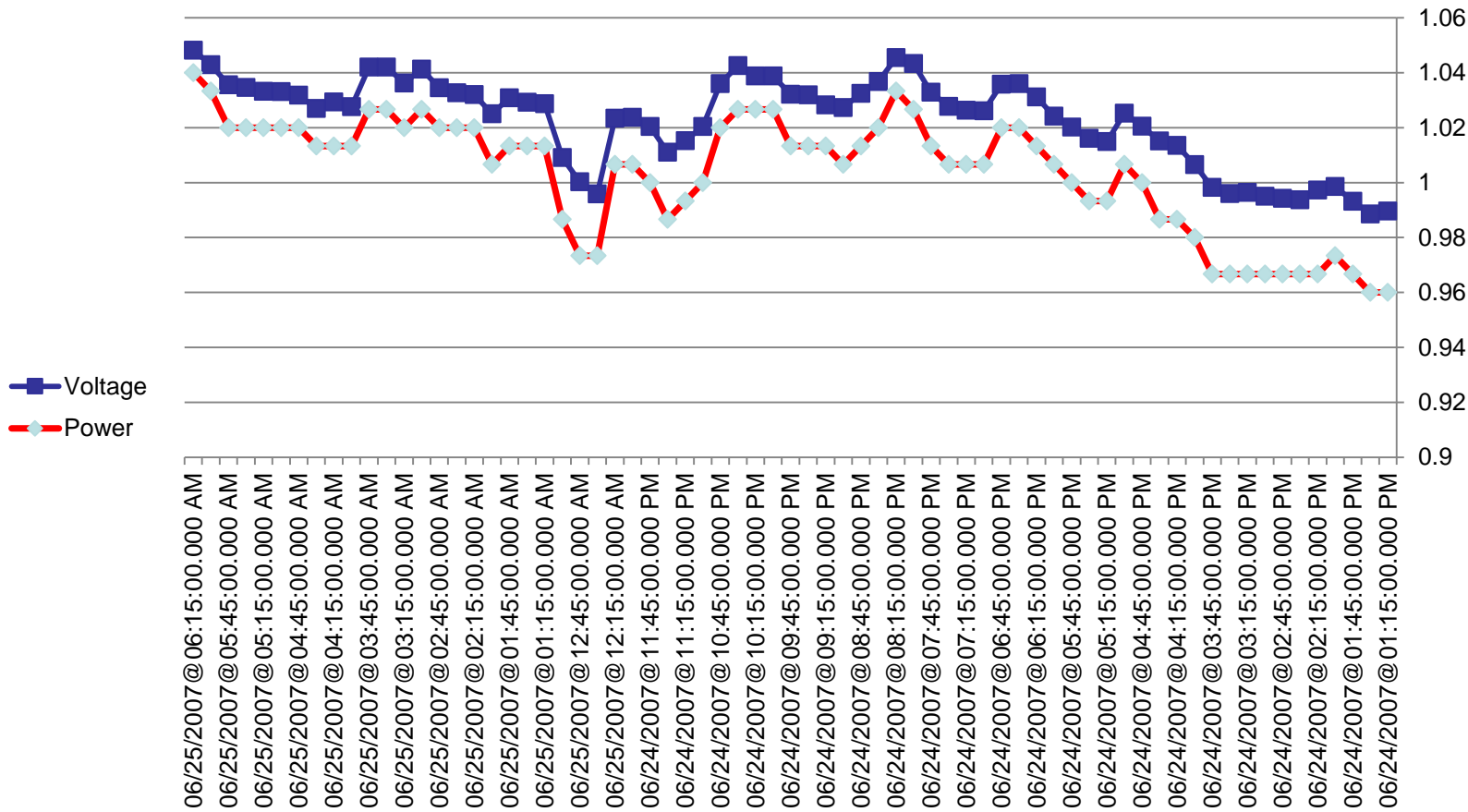
β_v : نمای تابع رگرسیون توان رآکیو

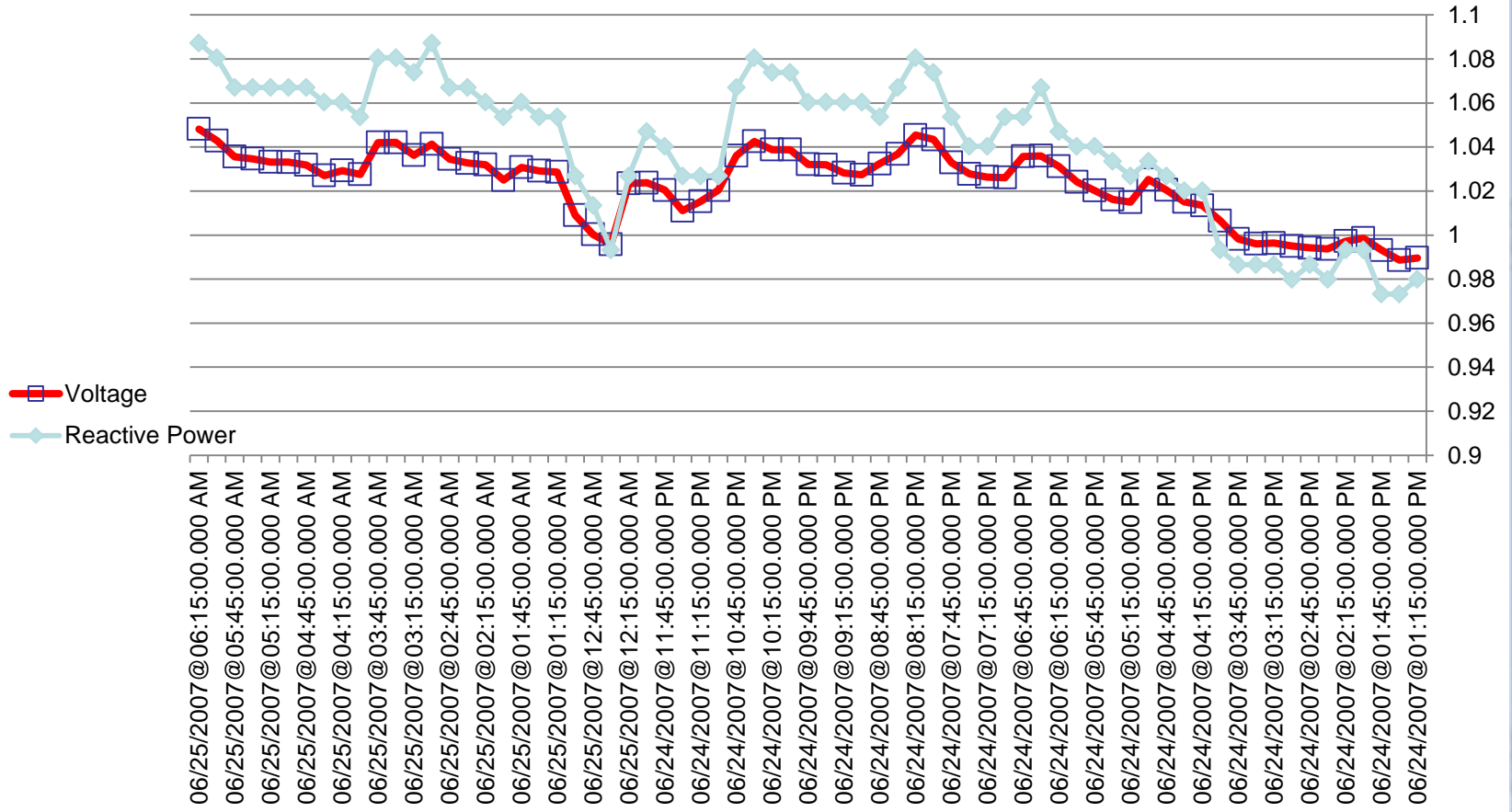
Pf	β_v	α_v	مولفه بار
1.0	0.0	2.0	بخاری برقی
0.75	2.5	0.5	سیستم تهویه اتاق (خانگی)
1.0	0.0	2.0	آبگرمکن
0.84	2.5	0.8	یخچال و فریزر
0.99	3.5	1.8	ماشین ظرفشویی
0.65	1.6	0.08	ماشین لباسشویی
0.77	5.2	2.0	تلویزیون رنگی
1.0	0.0	1.54	لامپ التهایبی
0.9	3.0	0.08	لامپ فلورسنت
0.87	1.6	0.08	فن و پمپ
0.84	2.5	0.2	پمپ آب گرم موتورخانه
0.83	0.6	0.1	موتورهای القایی کوچک
0.89	0.5	0.05	موتورهای القایی صنعتی

$$\alpha_v = 0 \quad \Rightarrow \quad P = P_0 \left[\frac{V}{V_0} \right]^0 \quad \Rightarrow \quad P = P_0$$

$$\alpha_v = 1 \quad \Rightarrow \quad P = P_0 \left[\frac{V}{V_0} \right]^1 \quad \Rightarrow \quad I = I_0$$

$$\alpha_v = 2 \quad \Rightarrow \quad P = P_0 \left[\frac{V}{V_0} \right]^2 \quad \Rightarrow \quad Z = Z_0$$



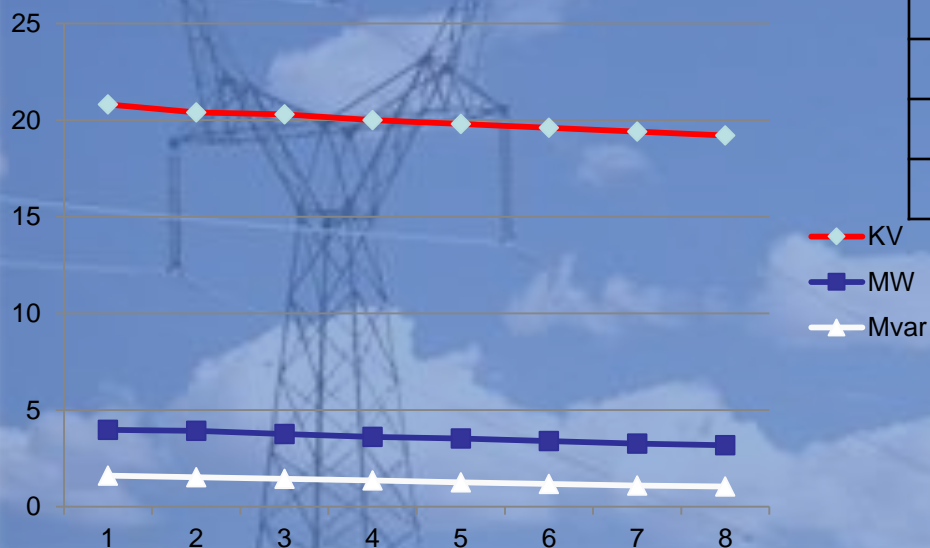


در روش استاندارد مورد استفاده برای این مطالعات که آزمون شکاف ولتاژ (Notch Test) نامیده می شود، حساسیت بار فیدر نسبت به کاهش ولتاژ در ابتدای فیدر با کاهش ولتاژ توسط تغییر تیپ ترانسفورماتور و اندازه گیری میزان توان قرائت شده اندازه گیری می شود.

فیدر فضائی - پست اندیشه - غرب استان

نتیجه : به ازای ۱/۵٪ کاهش ولتاژ ، حدود ۴٪ توان اکتیو و حدود ۶/۵٪ توان رآکتیو کاهش یافته است

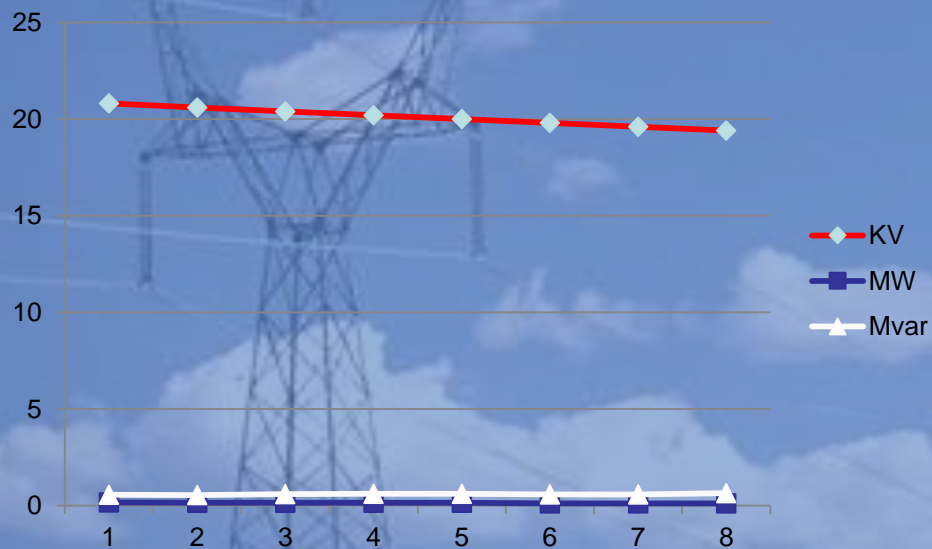
Tap	KV	MW	Mvar
9	20.8	3.98	1.61
8	20.4	3.92	1.52
7	20.3	3.76	1.45
6	20	3.62	1.36
5	19.8	3.53	1.26
4	19.6	3.39	1.18
3	19.4	3.27	1.09
2	19.2	3.18	1.04



فیدر انصاری - پست اندیشه - غرب استان

نتیجه : به ازای ۱٪ کاهش ولتاژ ، حدود ۰٪ توان اکتیو و حدود ۰٪ توان رآکتیو کاهش یافته است

Tap	KV	MW	Mvar
9	20.8	0.17	0.57
8	20.6	0.15	0.55
7	20.4	0.16	0.6
6	20.2	0.16	0.62
5	20	0.16	0.62
4	19.8	0.12	0.58
3	19.6	0.12	0.59
2	19.4	0.13	0.65

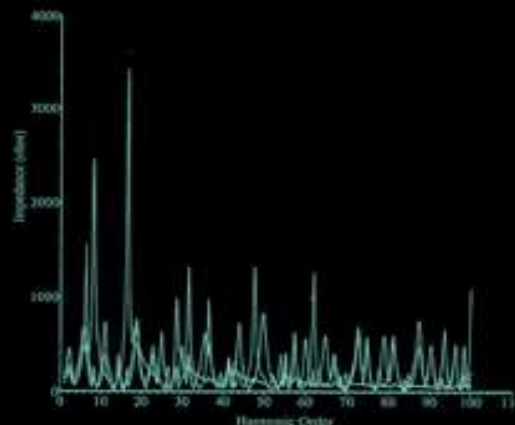


بررسی فیلترهای پاسیو برای جبران‌سازی

هارمونیکها



Power System Harmonics and Passive Filter Designs



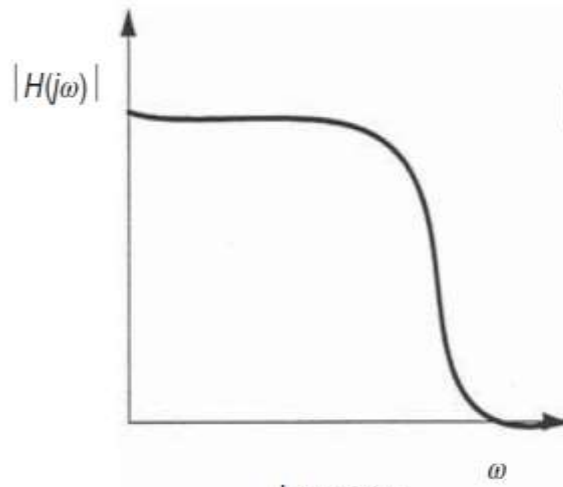
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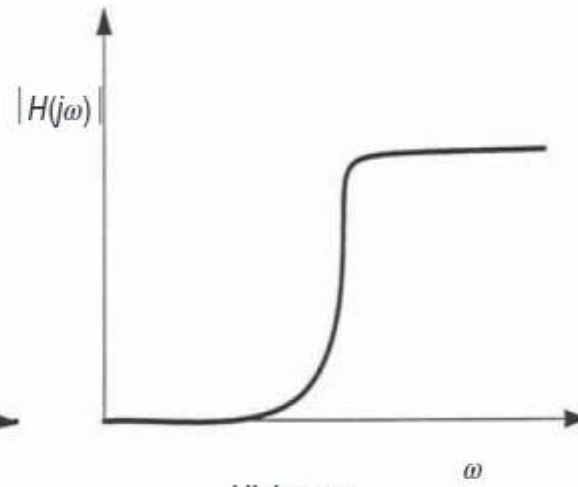


Mohamed E. El-Hawary, Series Editor

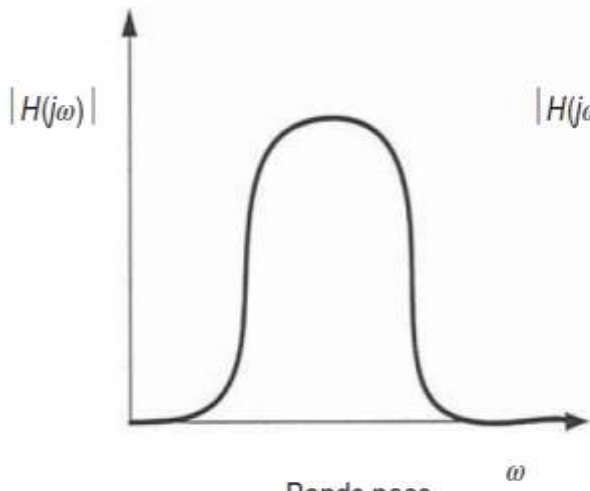
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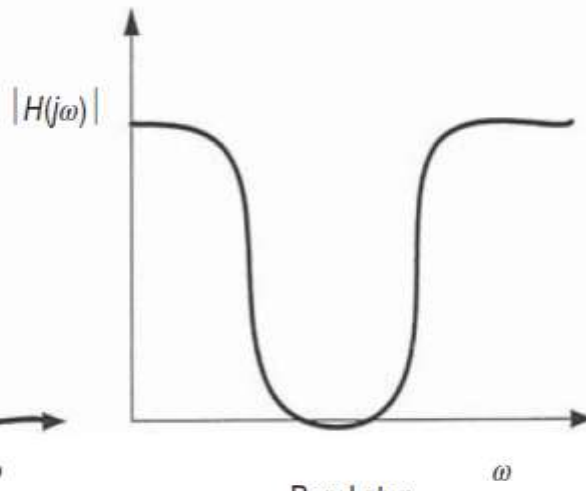
Low pass



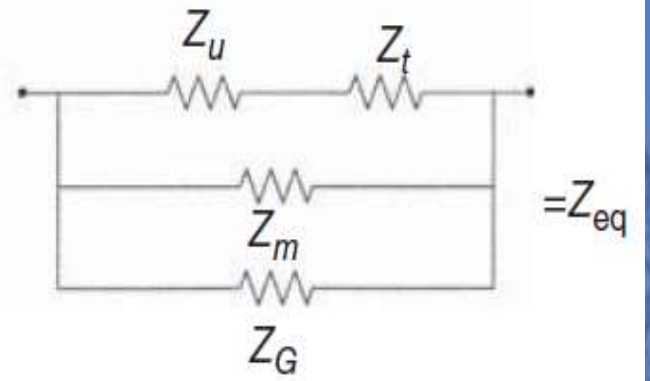
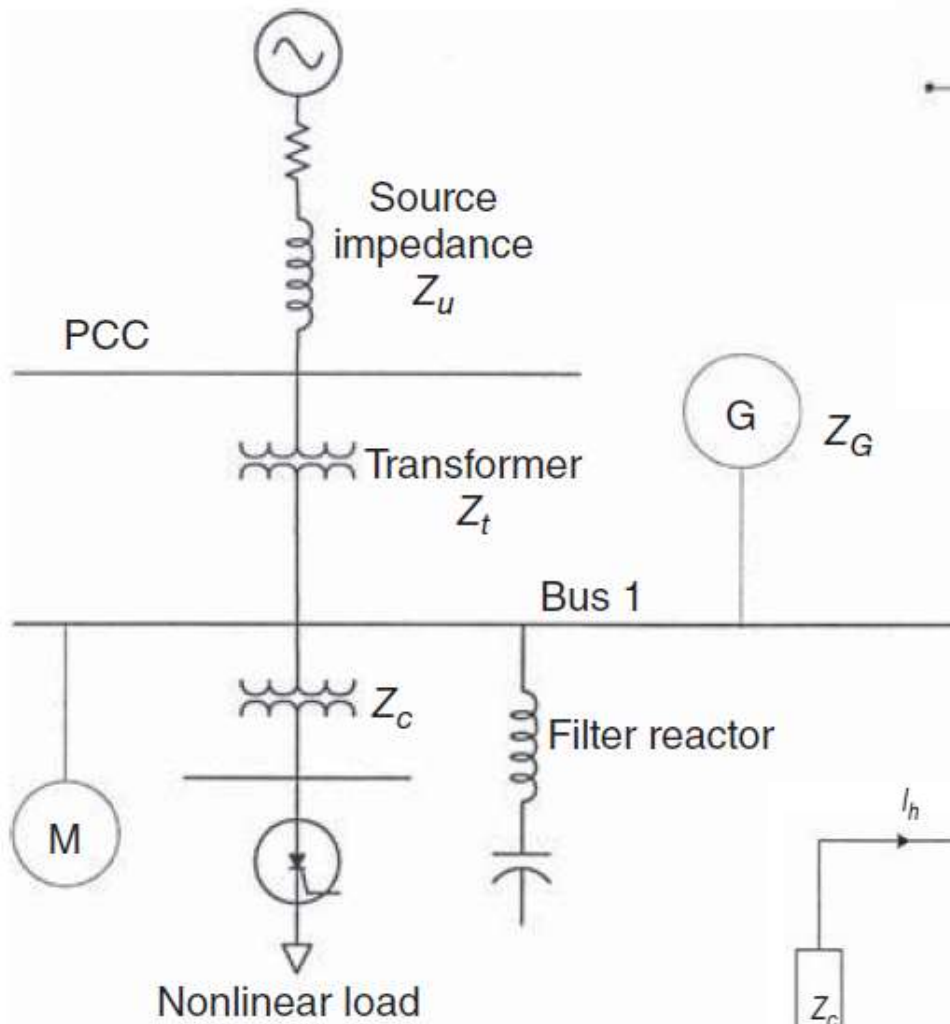
High pass



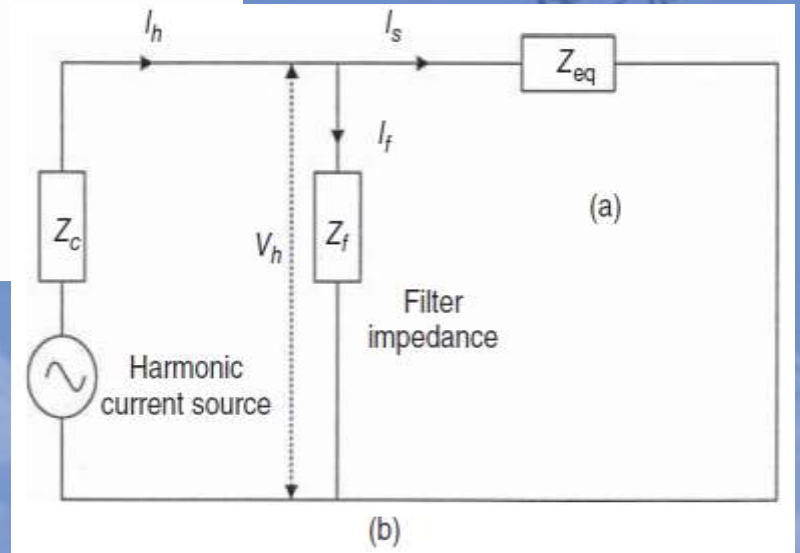
Bands pass



Band stop



Equivalent motor load Z_m



In an ST filter, as the inductive and capacitive impedances are equal at the resonant frequency, the impedance is given by the resistance R :

$$Z = R + j\omega_n L + \frac{1}{j\omega_n C} \quad (15.18)$$

At resonant frequency ω_n , $Z = R$.

The following parameters can be defined:

ω_n is the tuned angular frequency in radians and is given by

$$\omega_n = \frac{1}{\sqrt{LC}} \quad (15.19)$$

X_0 is the reactance of the inductor or capacitor at the tuned angular frequency. Here, $n = f_n/f$, where f_n is the filter-tuned frequency and f is the power system frequency.

$$X_0 = \omega_n L = \frac{1}{\omega_n C} = \sqrt{\frac{L}{C}} \text{ and } \omega_n = \sqrt{\frac{1}{LC}} \quad (15.20)$$

The quality factor of the tuning reactor is defined as

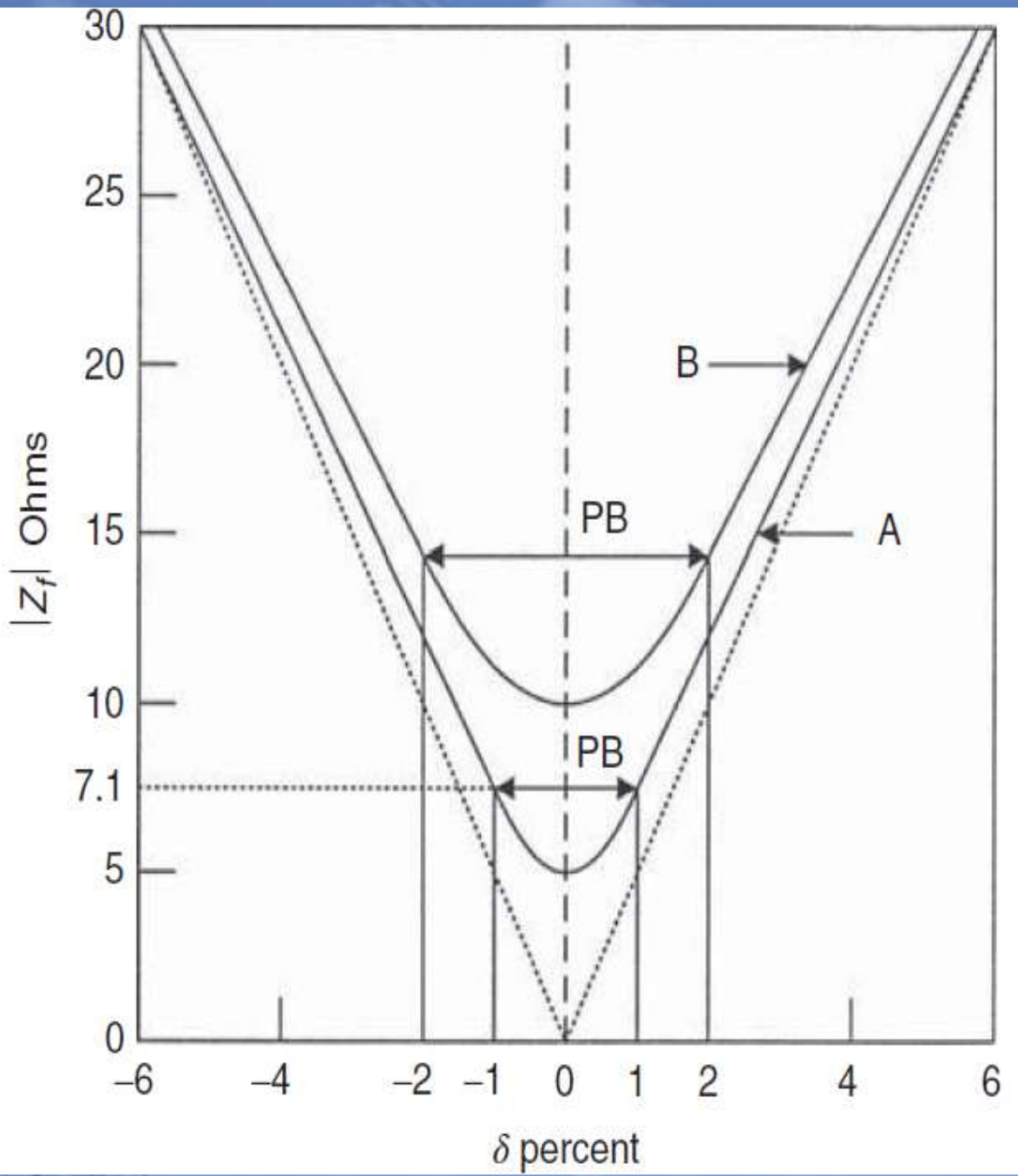
$$Q = \frac{X_0}{R} = \frac{\sqrt{L/C}}{R} \quad (15.21)$$

It determines the sharpness of tuning, see Chapter 3. The pass band is bounded by frequencies at which

At these frequencies, the net reactance equals resistance, capacitive on one side, and inductive on the other side. If it is defined as the deviation per unit from the tuned frequency, then for small frequency deviations, the impedance is approximately given by

$$|Z_f| = R\sqrt{1 + 4\delta^2 Q^2} = X_0\sqrt{Q^{-2} + 4\delta^2} \quad (15.24)$$

To minimize the harmonic voltage, Z_f should be reduced or the filter admittance should be high as compared to the system admittance.



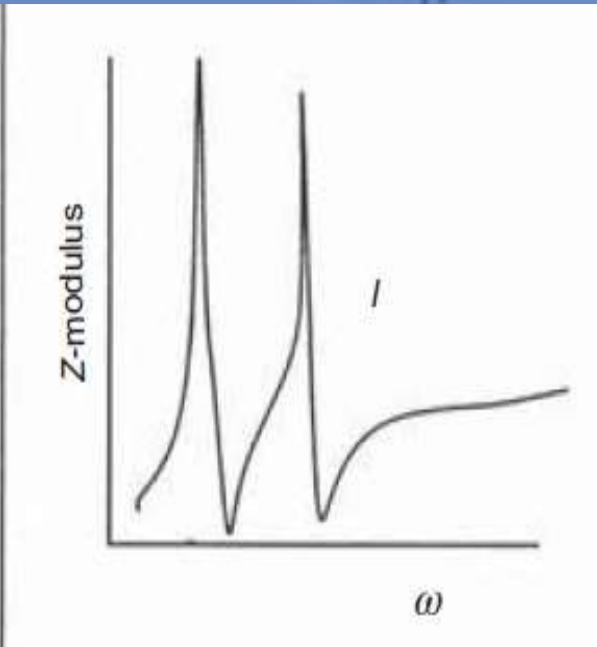
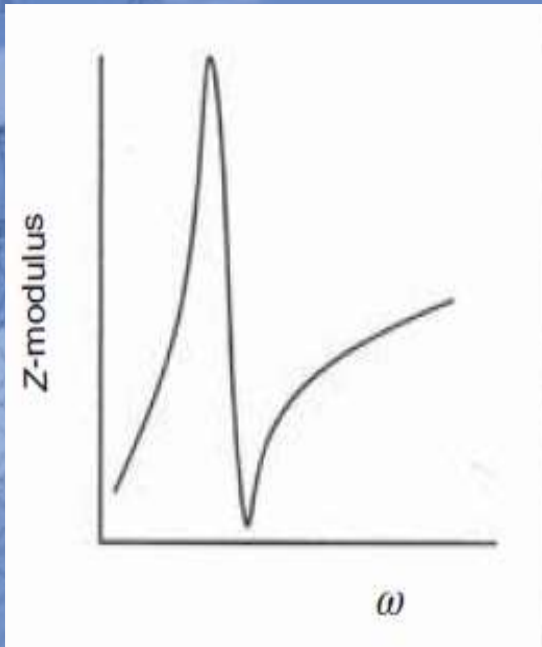
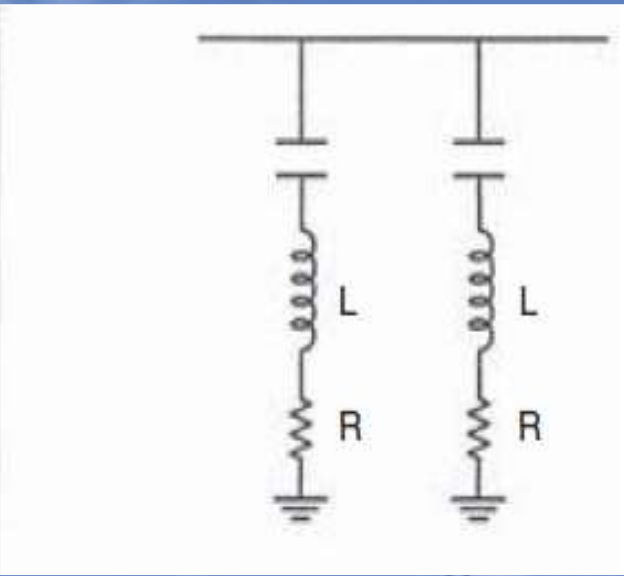
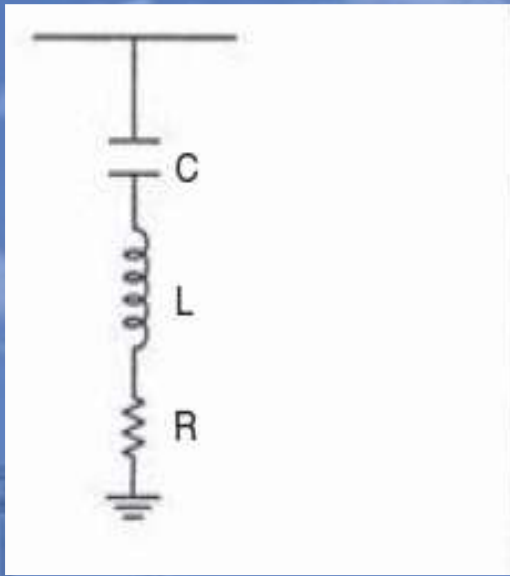
- The system frequency may change, causing harmonic frequency to change. The tolerance on filter reactors and capacitors may change due to aging or temperature effects.
- The tolerance on commercial capacitor units is $\pm 20\%$ and on reactors $\pm 5\%$. For filter applications, it is necessary to specify closer tolerances on capacitors and reactors. When a number of capacitor units are connected in series or parallel, these are carefully formed with tested values of the capacitance so that large phase unbalances do not occur. Any such unbalances between the phases will result in overvoltage stress; in addition, the neutral will not be at ground potential in ungrounded wye-connected banks. A tolerance of $\pm 2.0\%$ on reactors and $+5\%$ on capacitors (no negative tolerance) in industrial environment is practical. Closer tolerances may be required for high-voltage direct current (HVDC) applications.
- Tuning to exact harmonic, which is intended to be bypassed, may attract harmonics from the adjacent facilities and overload the filters.

A change in L or C of 2% causes the same detuning as a change of system frequency by 1% [3]:

$$\delta = \frac{\Delta f}{f_n} + \frac{1}{2} \left(\frac{\Delta L}{L_n} + \frac{\Delta C}{C_n} \right) \quad (15.28)$$

The filter impedance can also be written as

$$Z = R \left(1 + jQ\delta \frac{2 + \delta}{1 + \delta} \right) \quad (15.29)$$



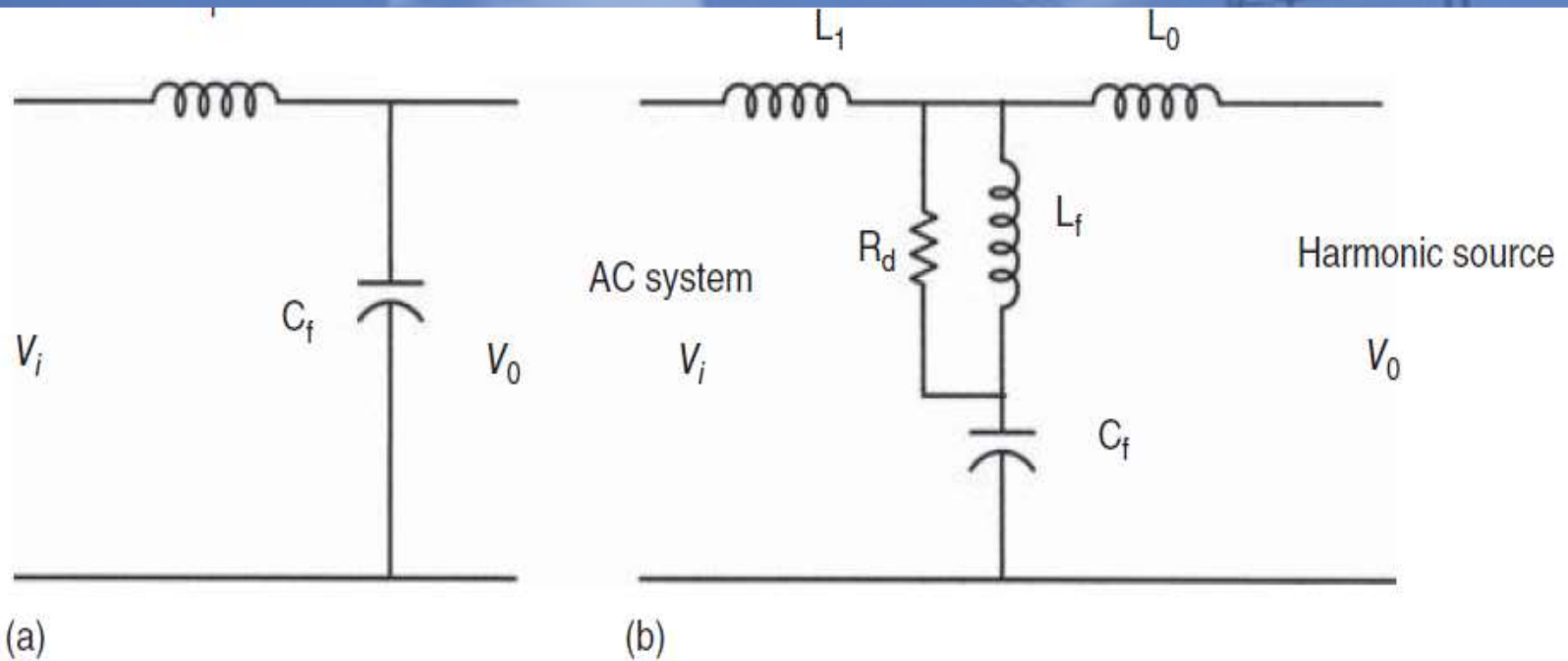


Figure 15.8 (a) An RC circuit as a bandpass filter and (b) an improved broadband filter for harmonic mitigation.

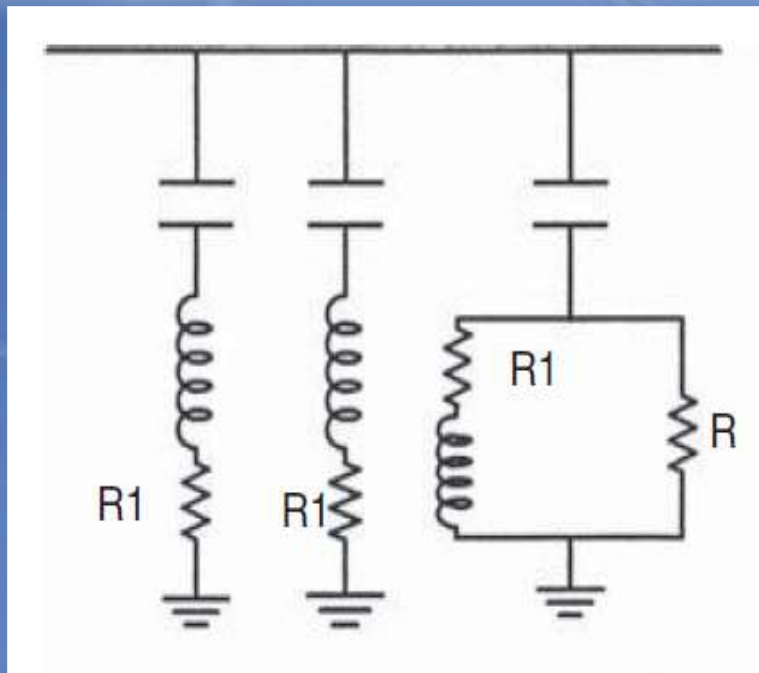
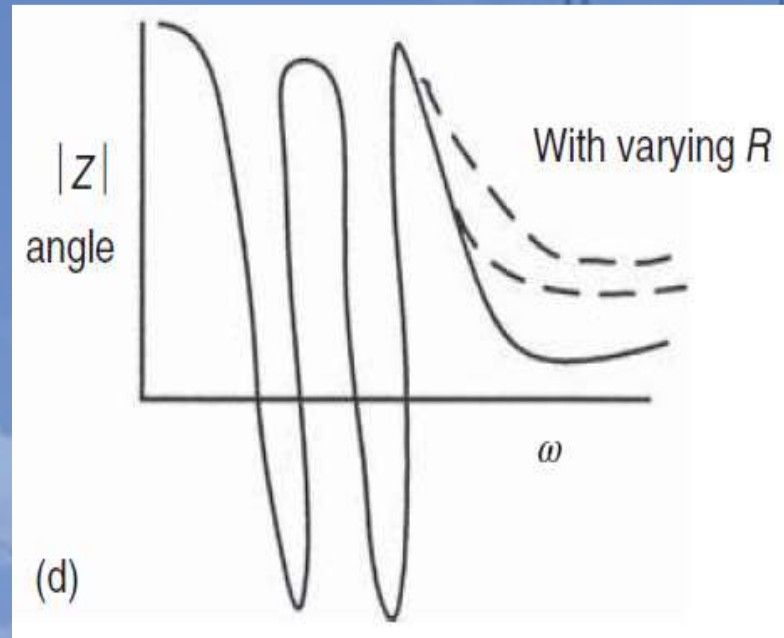
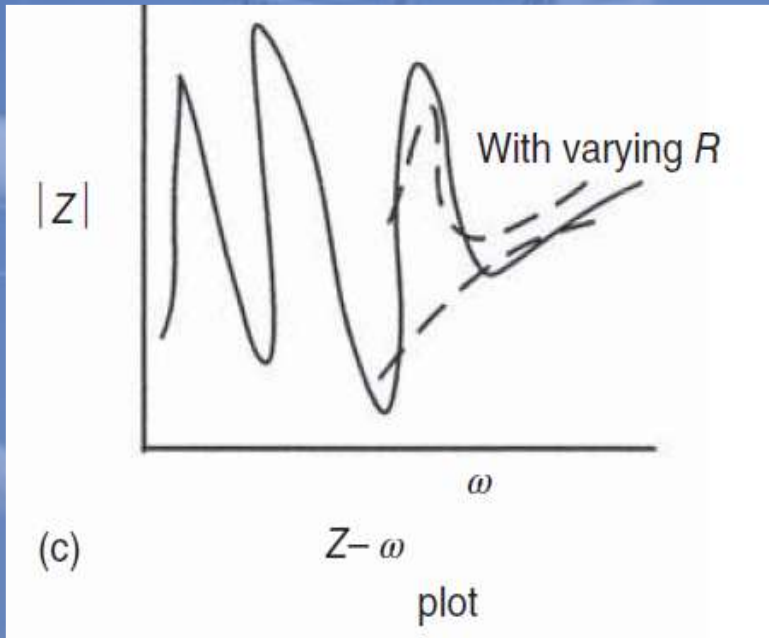


Figure 15.11 (a) Circuit of two parallel ST filters with a second-order high-pass filter, (b) $R-X$ plot, (c) $z-\omega$ plot, and (d) angle plot.





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**Thank you
And
Farewell**