(1)

Challenges: (Opportunities)

1/ Safety ←

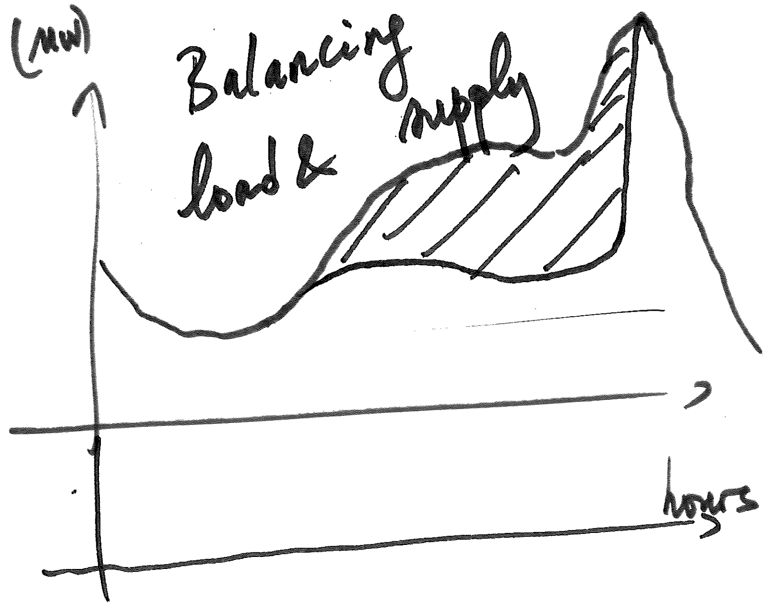
2/ Efficiency, reliability

3/ automation → [Cyber-security.]

~~Conf.~~ privacy.

4/ Storage

↳ EVs.



3/ Pollution

4/ Cost

5/ More renewable. (Inverter based generation).

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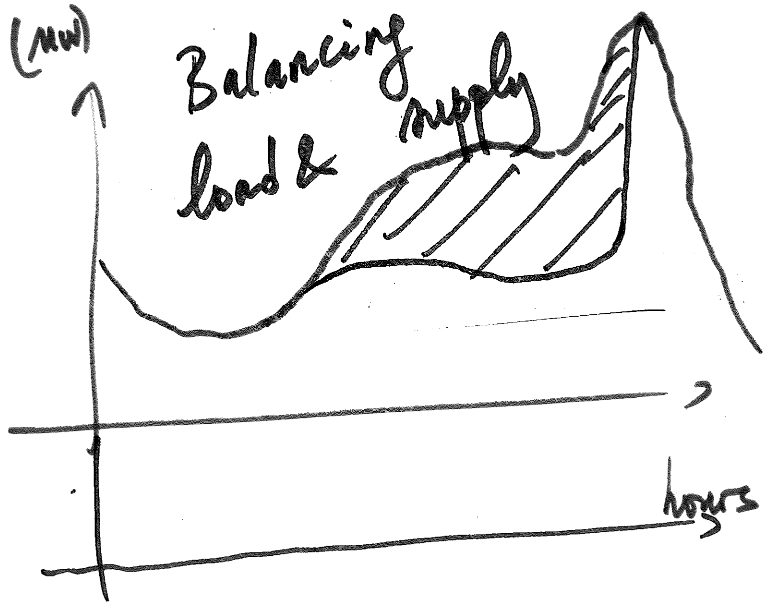

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AC systems:

$$v(t) = V_{max} \cos(\omega t + \delta)$$

- V_{max} → Magnitude / Amplitude
- ω → angular frequency
- δ → phase angle.

| 60 HZ
| 50 HZ

Japan 50 HZ / 60 HZ

Steinmetz

phasors.

$$\bar{V} = V_{rms}\, e^{j\delta} \quad \text{(exponential)}$$

$$= V_{rms} \angle \delta \quad \Big) \text{ Polar form}$$

$$= \underbrace{V_{rms} \cos\delta + j\, V_{rms} \sin\delta}_{\text{rectangular}}$$

Example: $i(t) = 100 \cos(\omega t + 60^\circ)$ [A]

Polar form: $\frac{100}{\sqrt{2}} \angle 60^\circ$ ✓ ok [A]

Exponential form: $\frac{100}{\sqrt{2}} e^{j60^\circ}$ [A].

Rectangular: $\frac{100}{\sqrt{2}} \left(\cos(60^\circ) + j \sin(60^\circ) \right)$.

$\frac{100}{\sqrt{2}} \left(\frac{1}{2} + j \frac{\sqrt{3}}{2} \right)$

Example: $\bar{V} = 100 \angle 45^\circ$ [V].

Instantaneous value $v(t) = 100\sqrt{2} \cos(\omega t + 45^\circ)$ [V]

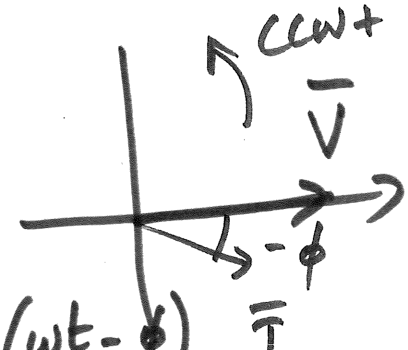
Real & reactive power & instantaneous power

$$p(t) = v(t) \cdot i(t)$$

$$v(t) = V_{max} \cos(\omega t) \longrightarrow \frac{V_{max}}{\sqrt{2}} \angle 0^\circ$$

$$i(t) = I_{max} \cos(\omega t - \phi) \longrightarrow \frac{I_{max}}{\sqrt{2}} \angle -\phi$$

$\bar{I}$ is lagging



$(\phi > 0)$

$$p(t) = V_{max} \cos(\omega t)\, I_{max} \cos(\omega t - \phi)$$

$$= V_{max} I_{max} \underbrace{\cos(\overset{A}{\omega t}) \cos(\overset{B}{\omega t - \phi})}$$

$$\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$$

$$p(t) = \frac{V_{max} I_{max}}{2} \left[\cos(2\omega t - \phi) + \cos(\phi)\right]$$

$$2 = (\sqrt{2} \cdot \sqrt{2})$$

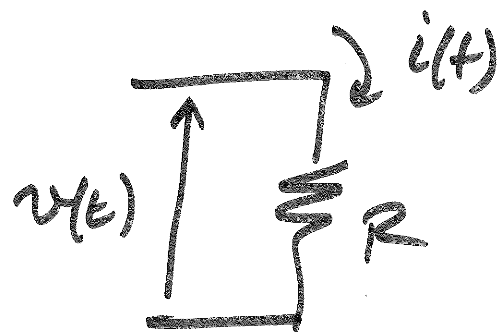
$$p(t) = V_{rms} I_{rms} \left[\cos(2\omega t - \phi) + \cos(\phi) \right].$$

$$P_{AVE} = V_{rms} I_{rms} \cos(\phi)$$

↳ Real power.

$$F_{AVE} = \frac{1}{T} \int_0^T f(t)\,dt$$

Example:



$$v(t) = V_{max} \cos(\omega t)$$

$$i(t) = I_{max} \cos(\omega t - \phi)$$

0

$$p(t) = V_{max} I_{max} \cos^2(\omega t)$$

1

$$= \frac{V_{max} I_{max}}{2} \left[\cos(2\omega t) + \cos(\phi) \right]$$

$$p(t) = V_{rms} I_{rms} \left[\cos(2\omega t) + 1 \right]$$