



Ministerie van Economische Zaken



EMC Aspects of Power Quality



From Ohm's Law to Smart Grids

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UNIVERSITY OF TWENTE.
TELECOMMUNICATION ENGINEERING.

in cooperation with
THALES  Environmental
Competence
Centre



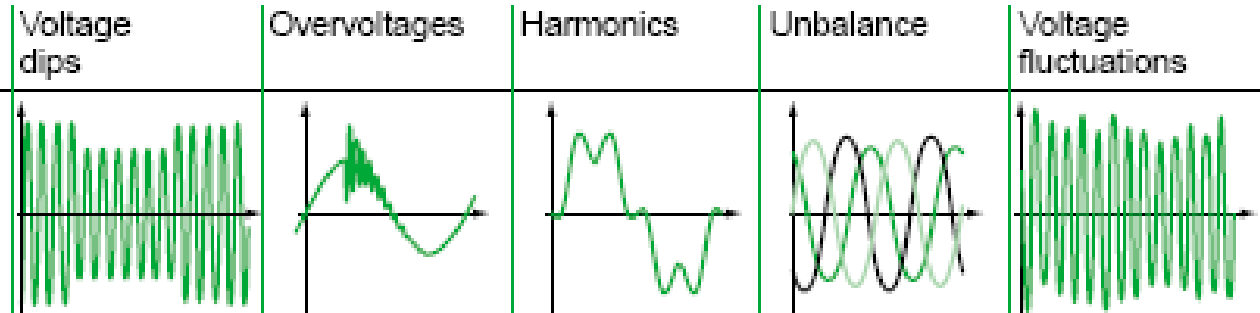
Power Quality: Phenomena Based

(more or less) addressed in military and civil standards

Phenomena	
Voltage Tolerance	Inrush/Starting Current
Voltage Interruptions	Power Factor
Voltage Excursion	Frequency Excursion
Emergency/ Fault Condition (V)	Emergency/ Fault Condition (F)
Voltage Surge	Pulsed Loads
Voltage Transient	Flicker
Voltage Unbalance	Inter Harmonics
Voltage Deviation Factor	Mains Signalling

Disturbances

Characteristic waveforms



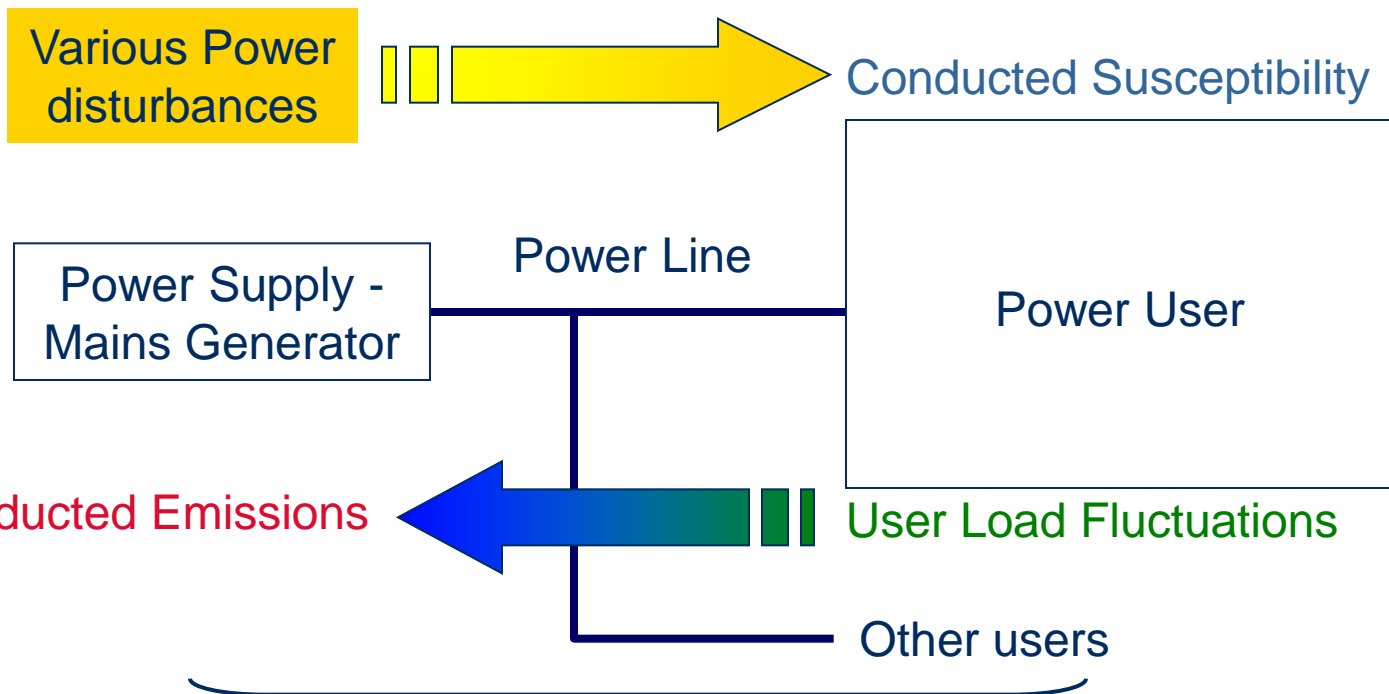


Power Quality: influence of power-users



EMI related; Compatibility required

“Voltage Quality” or “Quality of Supply”



“Current Quality” or “Quality of Consumption”

Reference: Bollen, Math H.J. “[Understanding Power Quality Problems](#)”, IEEE Press, 2000
ISBN 0-7803-4713-7, IEEE Order Number PC5764

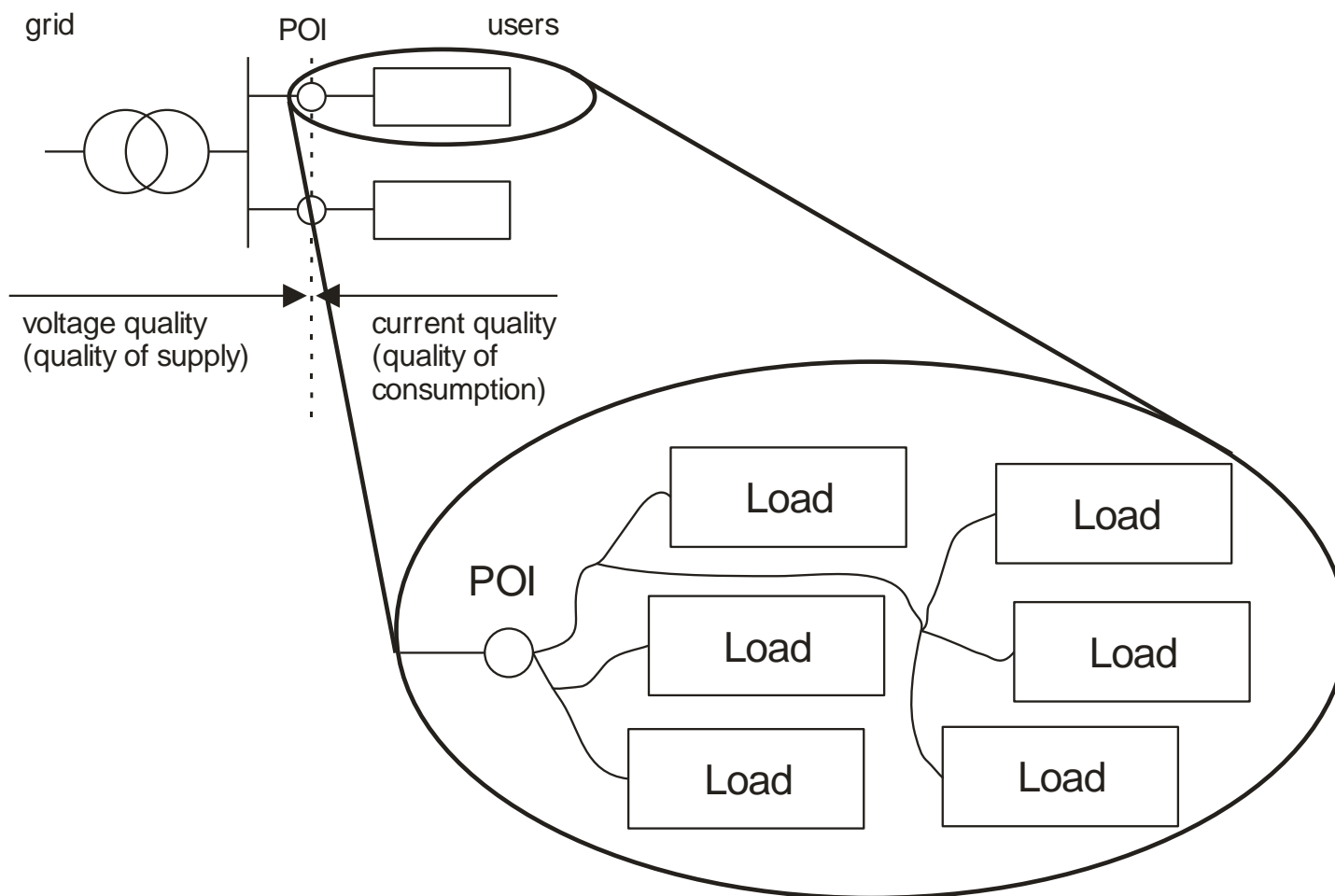
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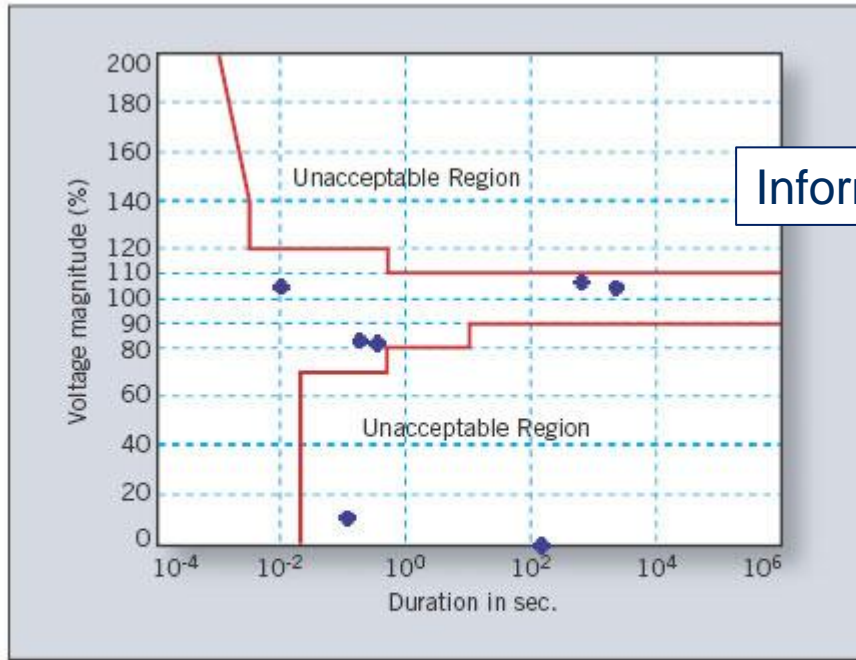
Interference Problems due to User Load Currents



traditional model: all users are loads



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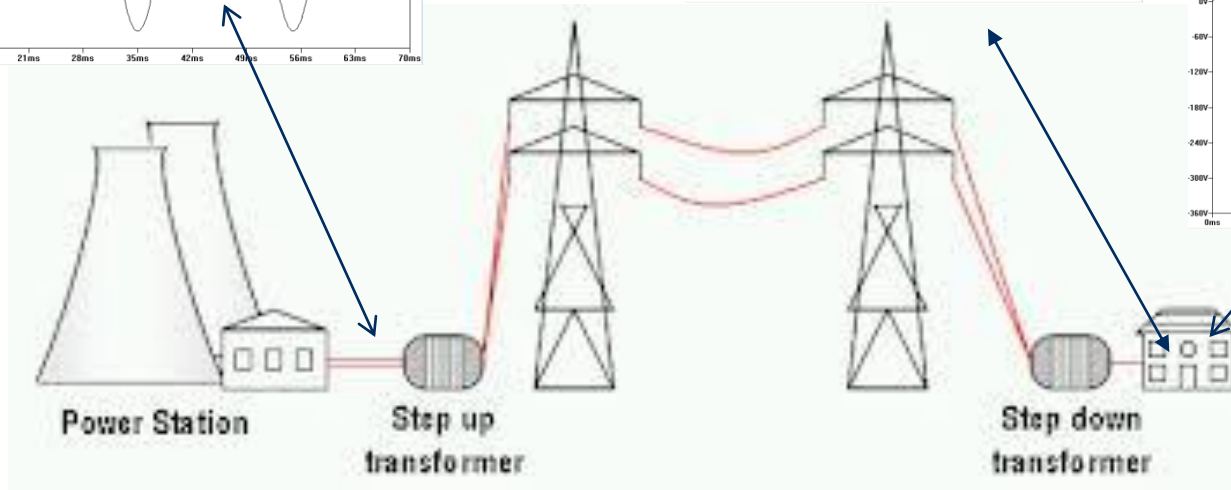
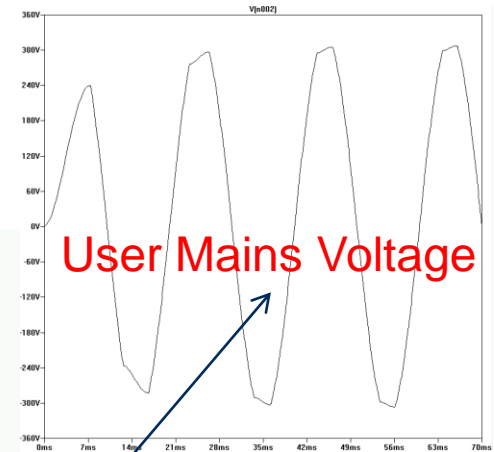
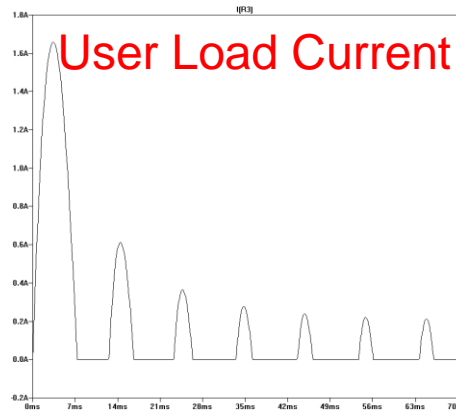
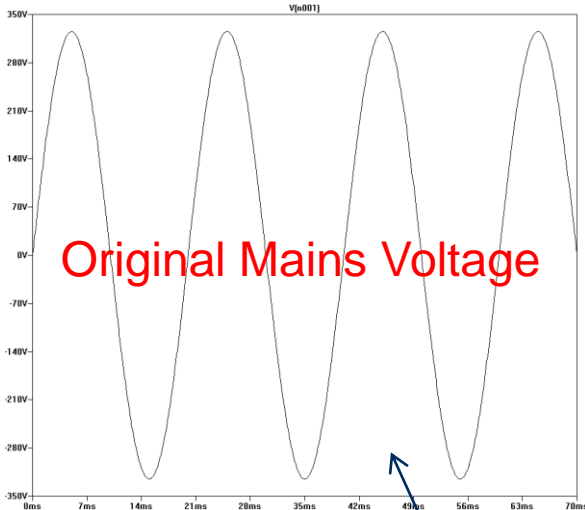
Information Technology Industry Council

Shows what voltage excursions are allowed on the mains and for how long i.e. the Voltage Tolerance of Equipment

Non-Sinusoidal Currents and Ohm's Law



the root cause of most power-quality related problems



$$\Delta V = \Delta I \times R_{\text{LINE}}$$

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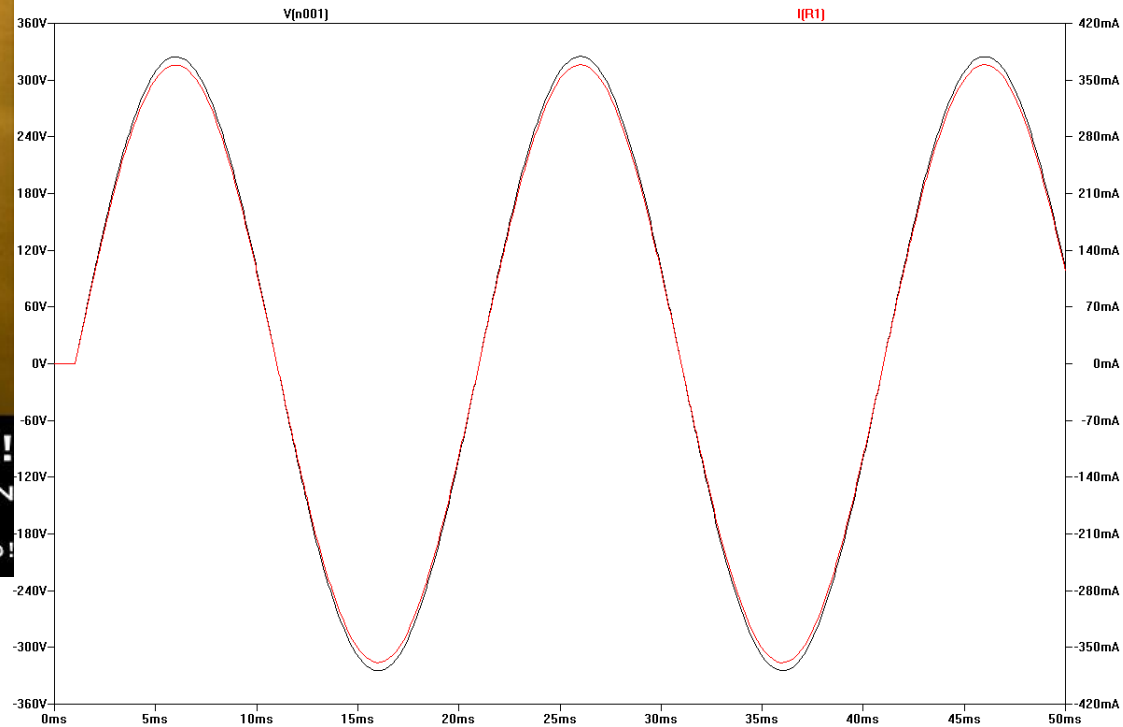
Mains Voltage and Current as Users Like to See It



clean sine wave voltage and resistive load

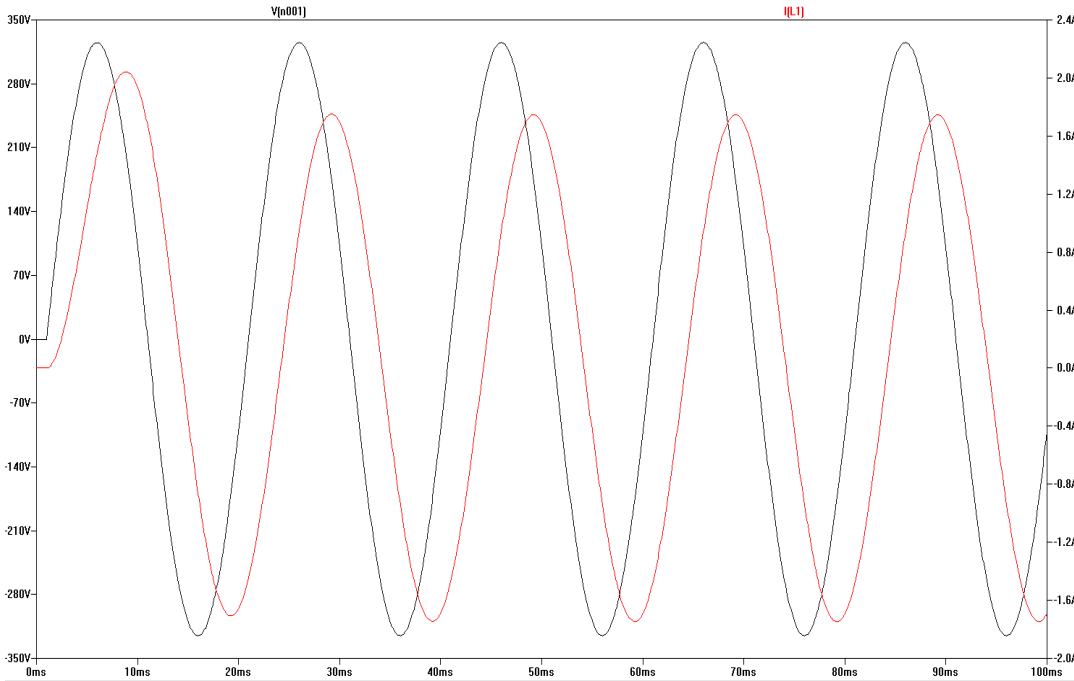


LANG LEVE DE GLOEILAMP!
VOOR EEN GEZOND GROEN ÉN GELUKKIG LEVEN
DOE MEE! STOP HET ONEIGENLIJKE GLOEILAMPENVERBOD!

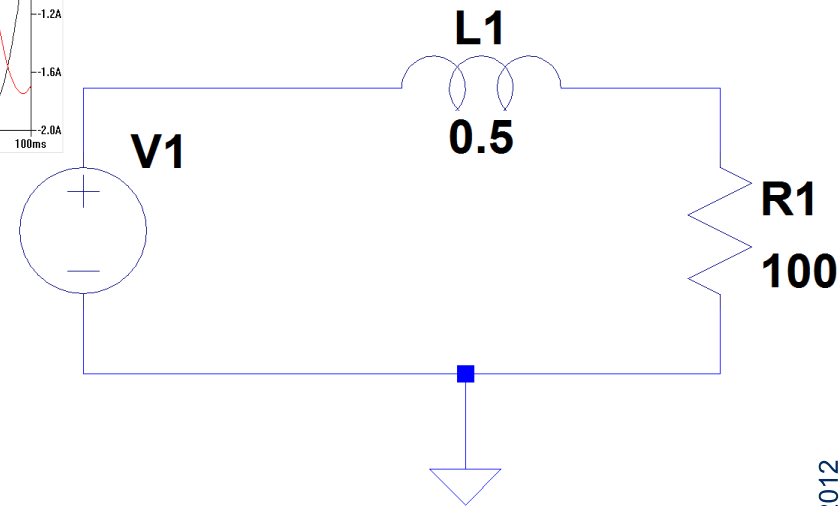
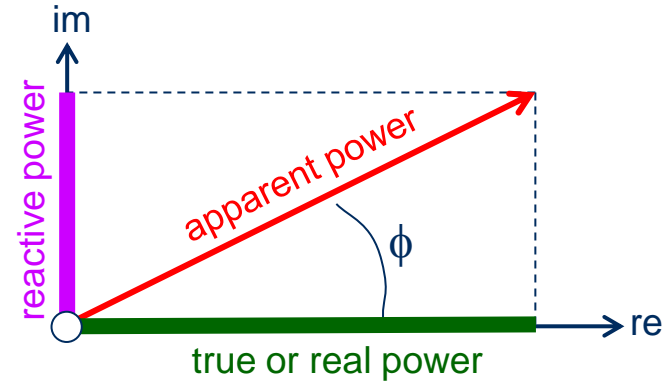


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History: Reactive Loads



result: phase shift, cosine(ϕ)



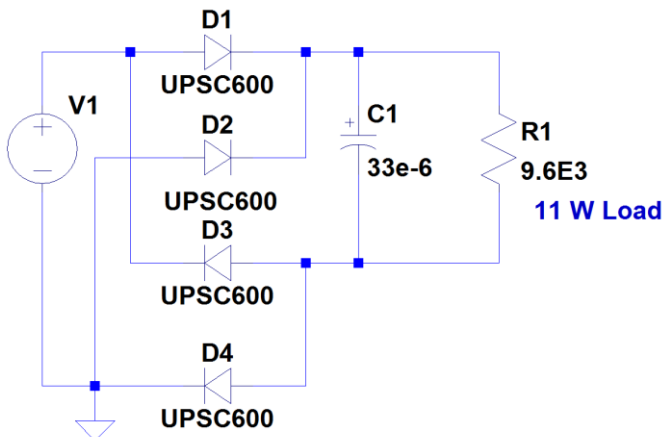
```
SINE(0 325.27 50 1e-3 0 0 10)
.tran 0 0.1 0 1e-4
```



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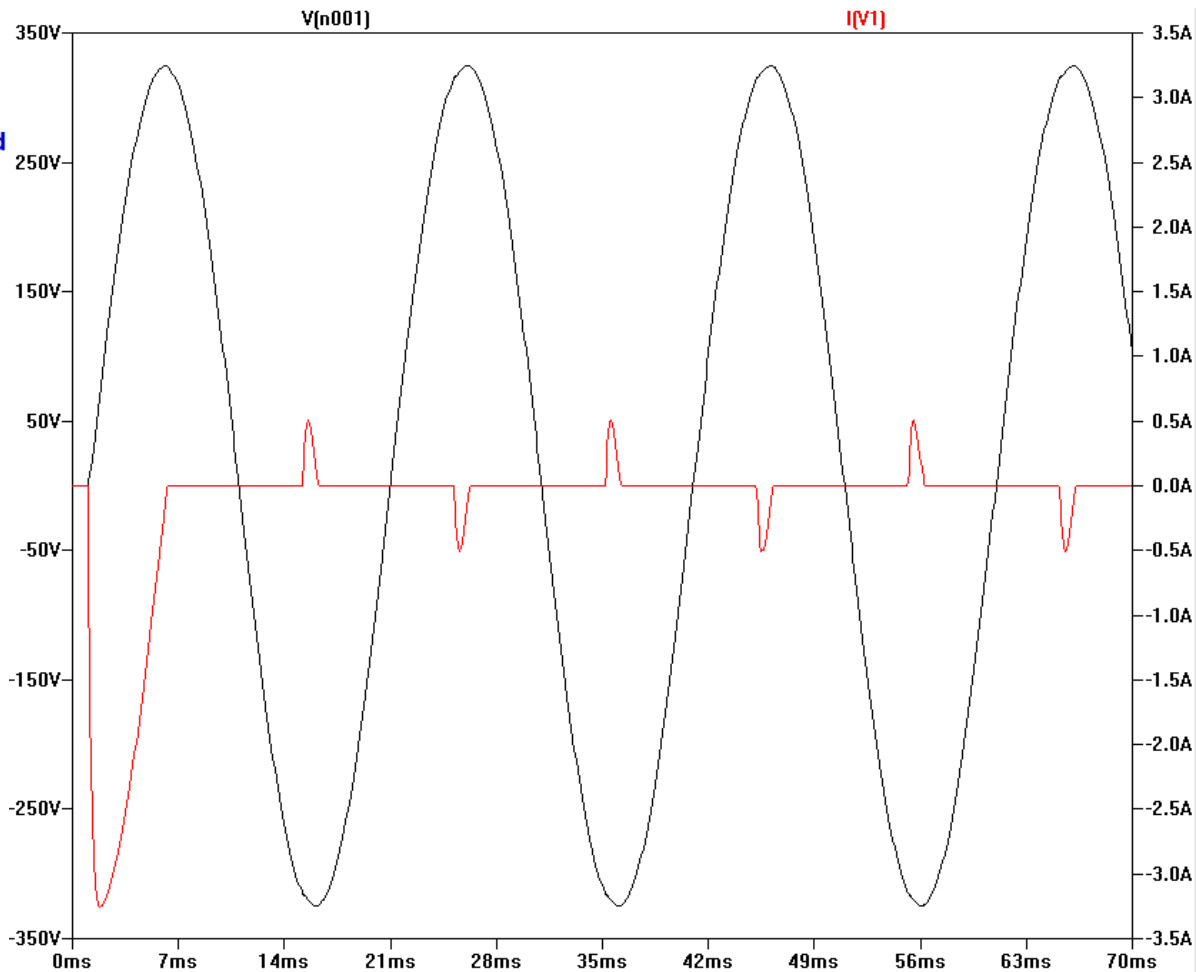
most prominent: diodes charging bulk capacitors



```
SINE(0 325.27 50 1e-3 0 0 50)
Rser=4
.tran 0 0.07 0 1e-4
```

Legend

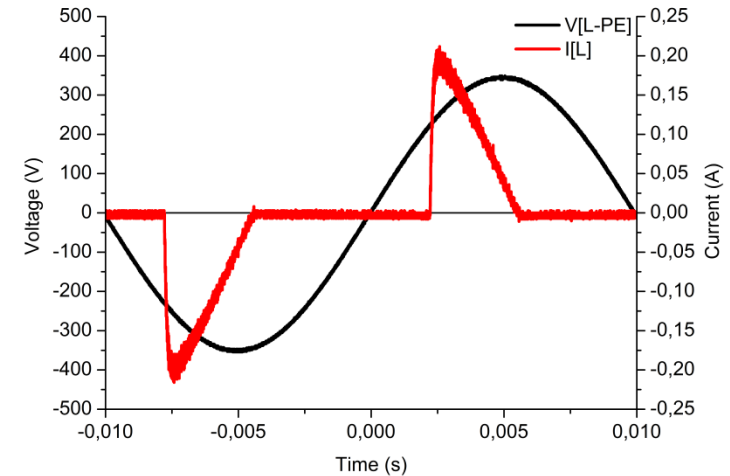
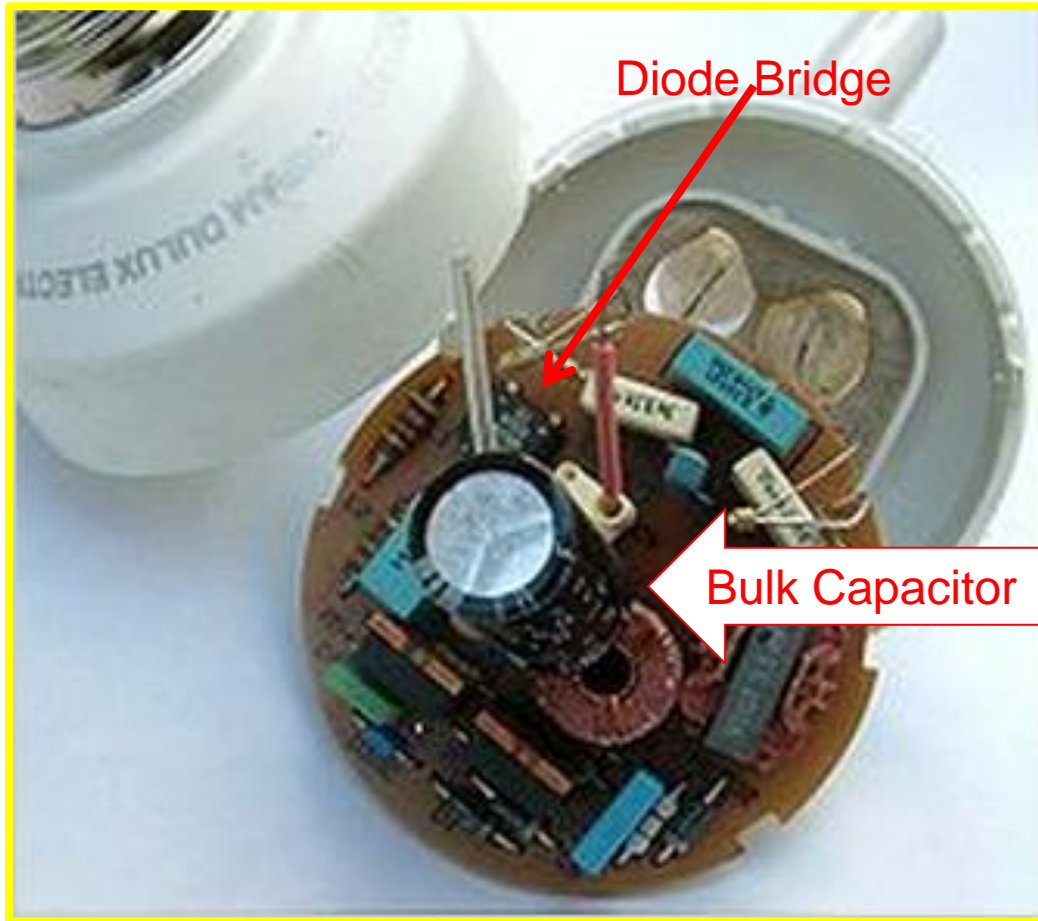
- Mains Voltage
- Mains Current



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Modern Compact Fluorescent Lamp (CFL)

electronic circuit with diode bridge and bulk capacitor



Current Waveform
on a "Decent" Sine-Shaped
Voltage Waveform

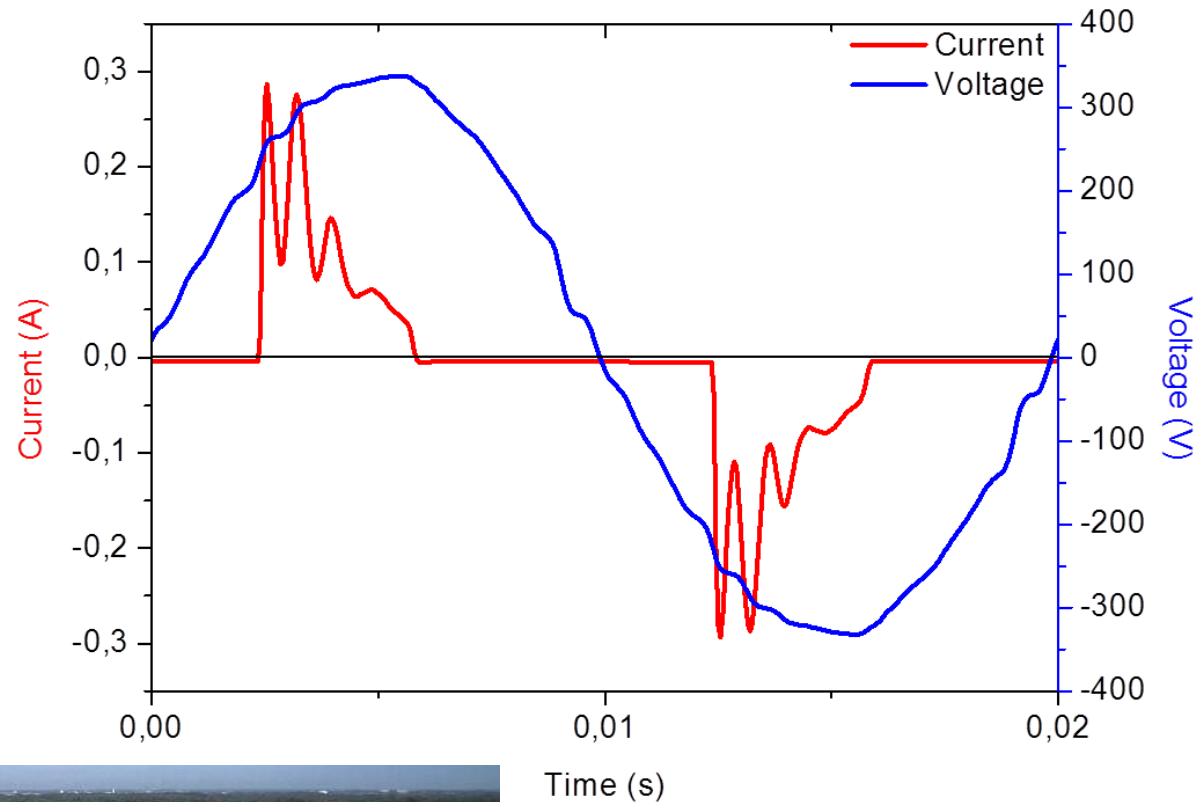
Source: Wikipedia

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Problem with Diode Rectifiers: Synchronicity



all conduct simultaneously on mains voltage! distortion adds up



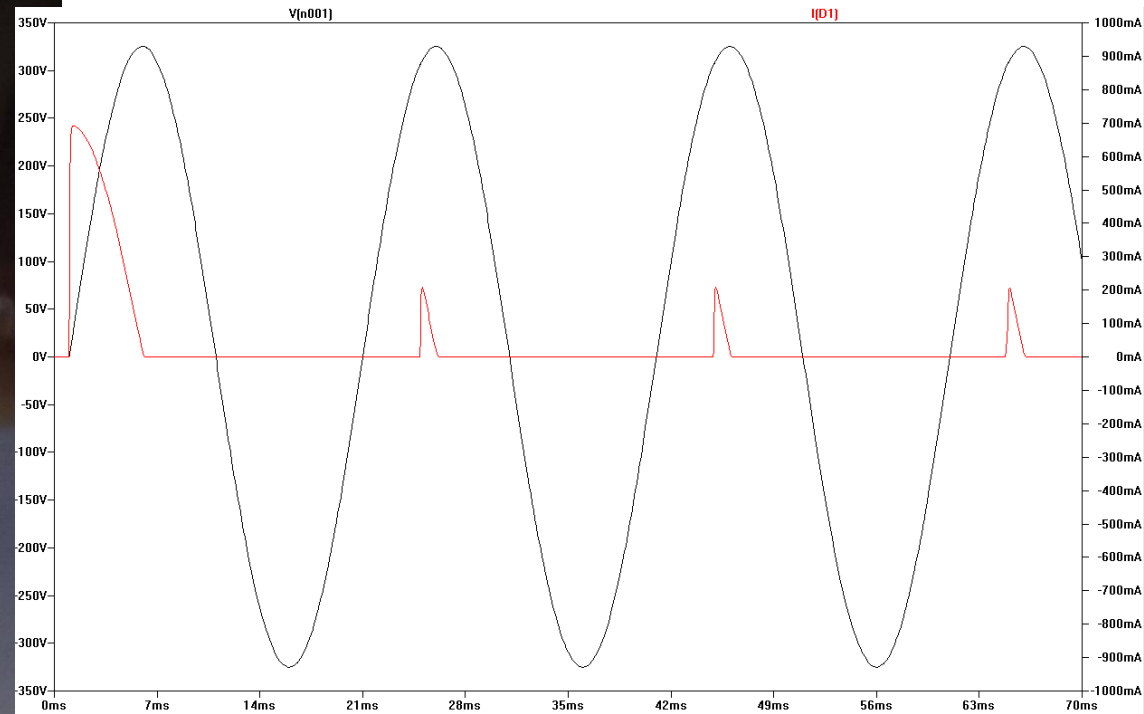
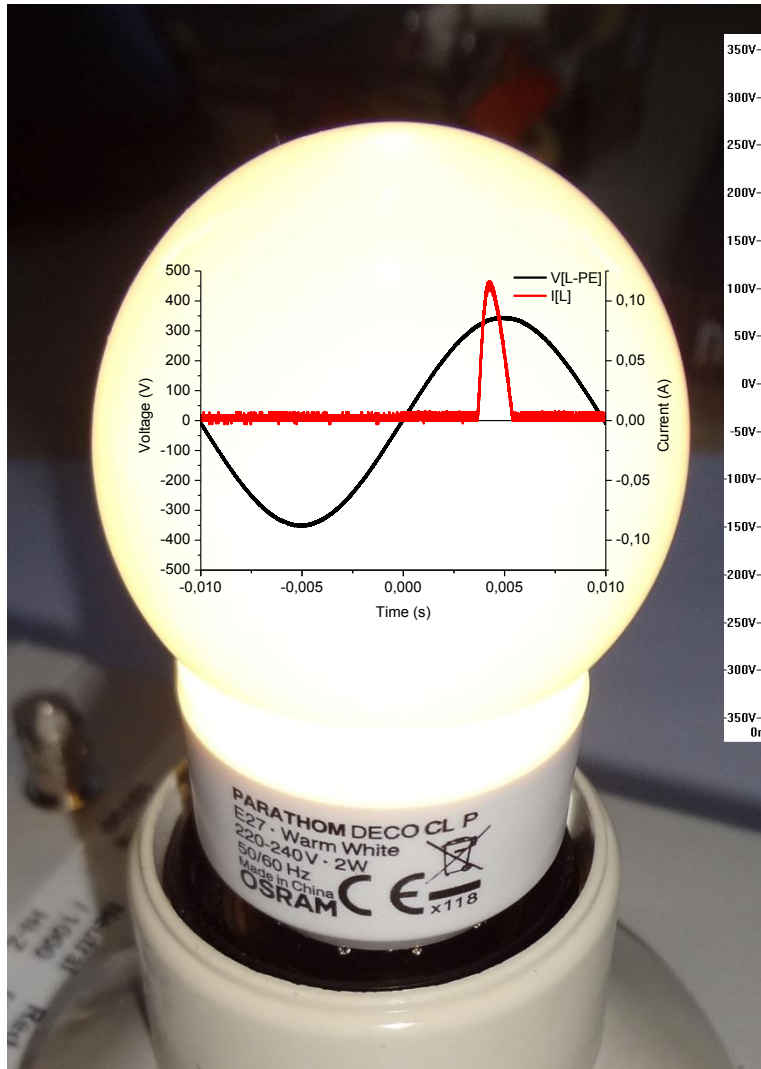
Same Fluorescent Lamp
in Large Office Building
with distorted Voltage



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this specific version even has single phase rectification!



With many of these lamps in parallel, a considerable DC current will be injected into the power-net!

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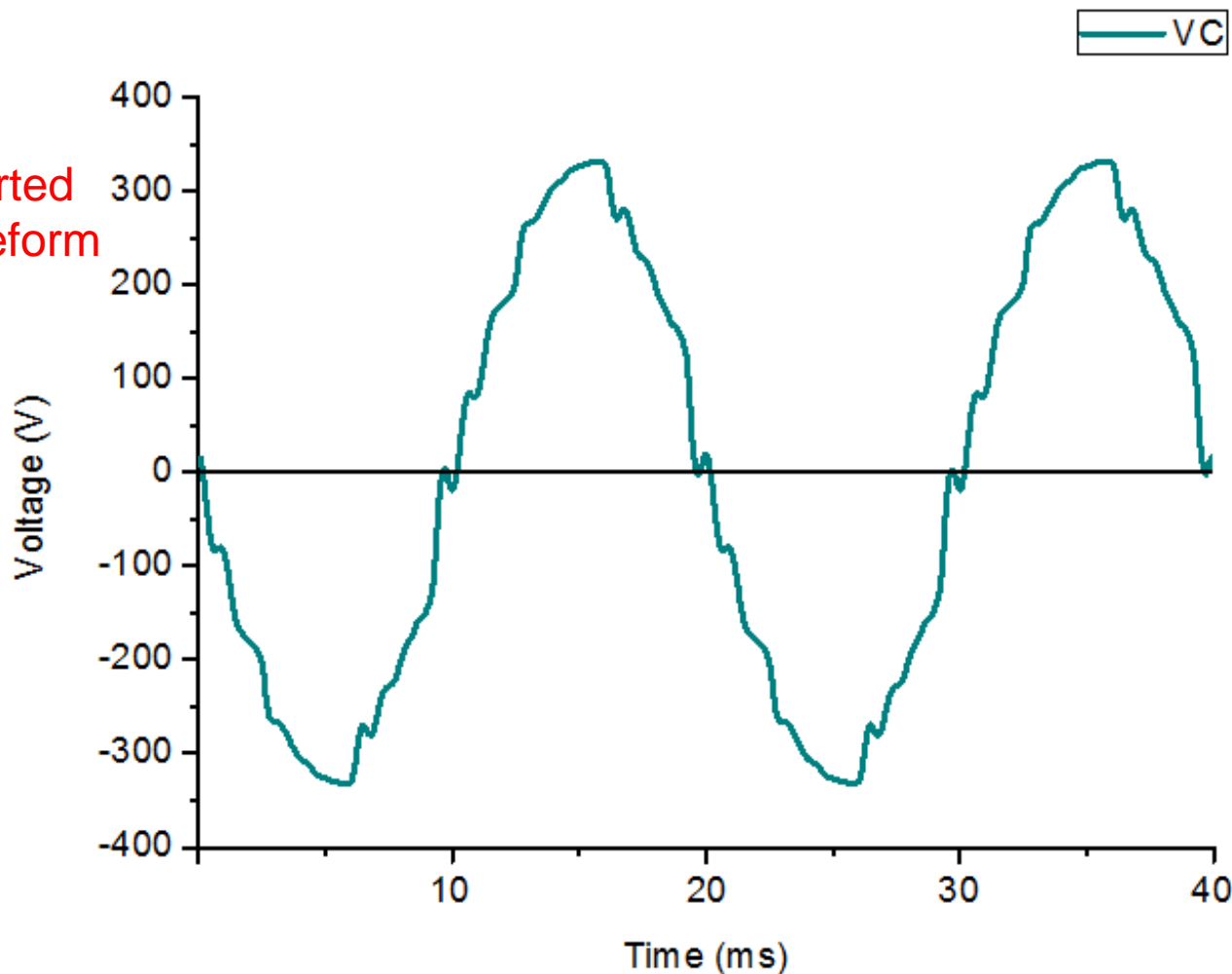


Small Users <75 W Have No PF Requirements



e.g. all LED's , CFL's and many laptops are exempt

Effect....
Heavily Distorted
Voltage Waveform



Wave-Shape in Large Office Building: Multiple Zero Crossings!

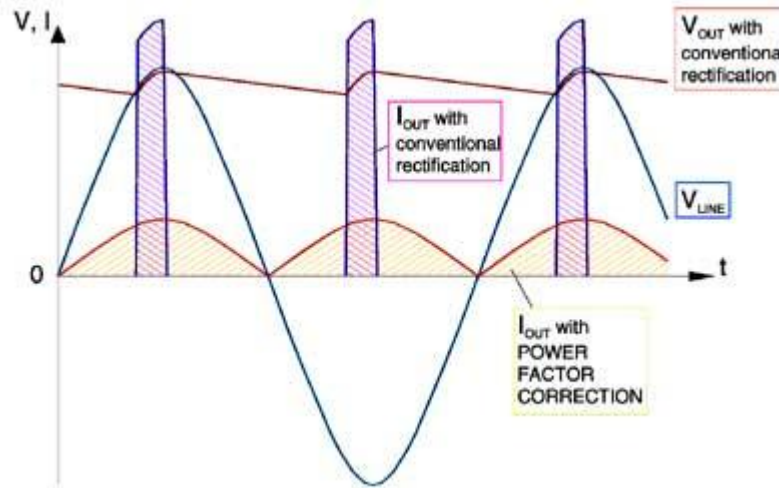
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The Power Factor (PF) as a Replacement for Cos(φ)



to mitigate the distortion problem: target PF should be "1"



$$PF = \cos(\phi) \cdot \frac{I_{50\text{ Hz}}^*}{I_{\text{total}}}$$

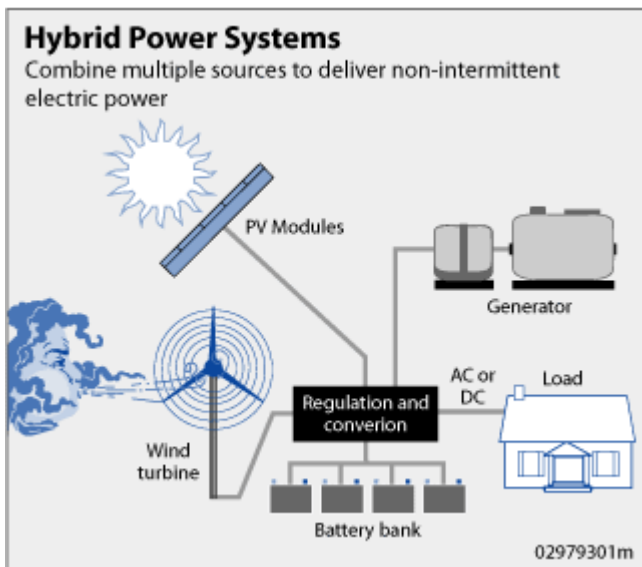
*Only correct for an undistorted (Sinusoidal) Voltage Waveform

NOTE:
 PF corrected means: mimic Ohmic Load.
 PFC does NOT improve Wave-Shape!

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installations with local power generation not or loosely coupled to a main grid



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The Risk of Power Islands: Overproduction

mains voltage too high at high illumination levels



**>253 VAC
@ 45 KVA
generation**

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Mechanism of Overvoltage at Sunny Days: Ohm's Law



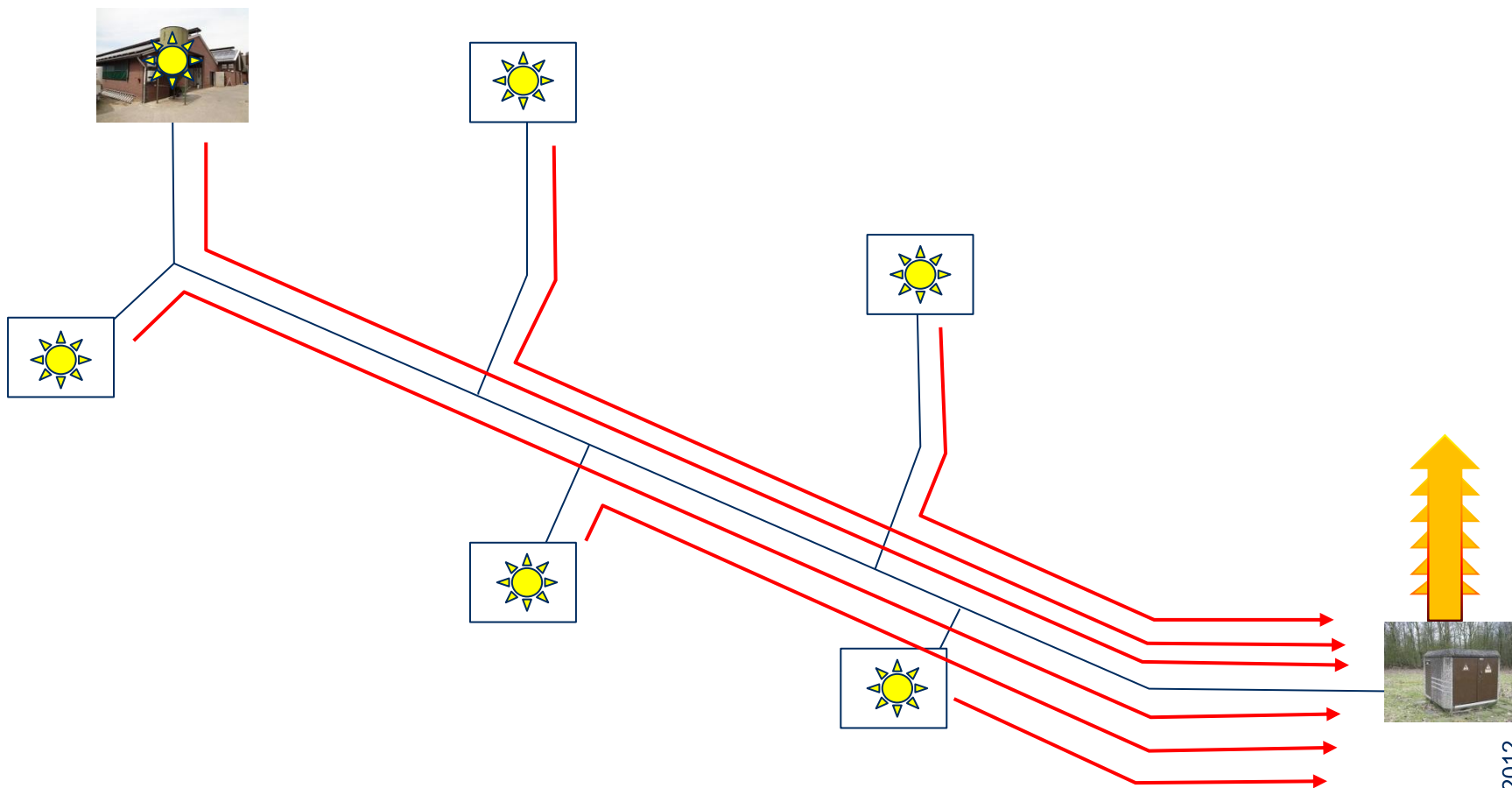
farm's powercable cannot handle 45 KVA in the opposite direction





What if all Neighbours Install Solar Panels?

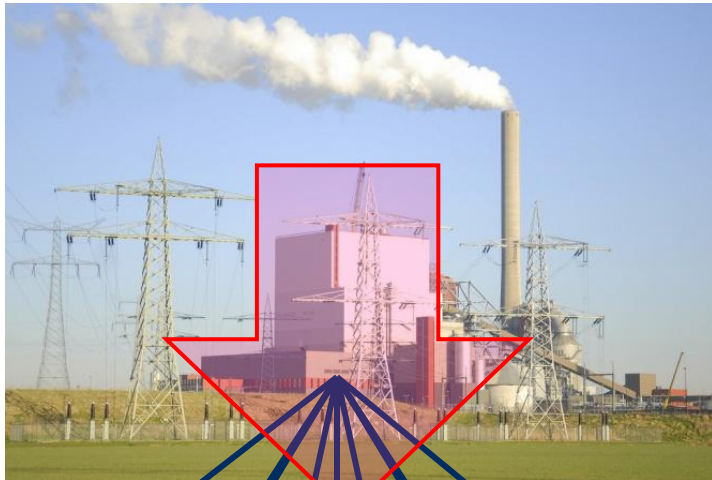
like the little lamp-currents, many small ones make one big one!



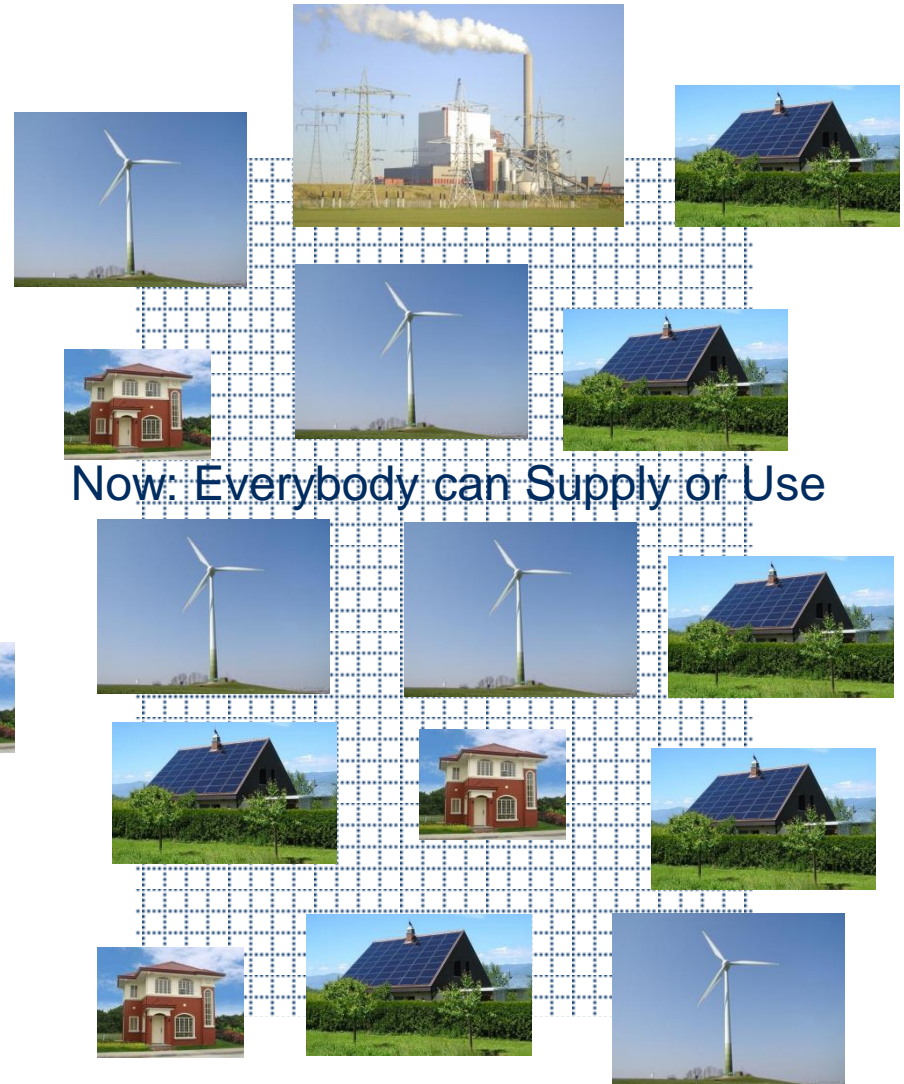
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How to Solve these Conflicts?

supply and demand, storage, who is in control?



Traditional: One Way Traffic



Now: Everybody can Supply or Use

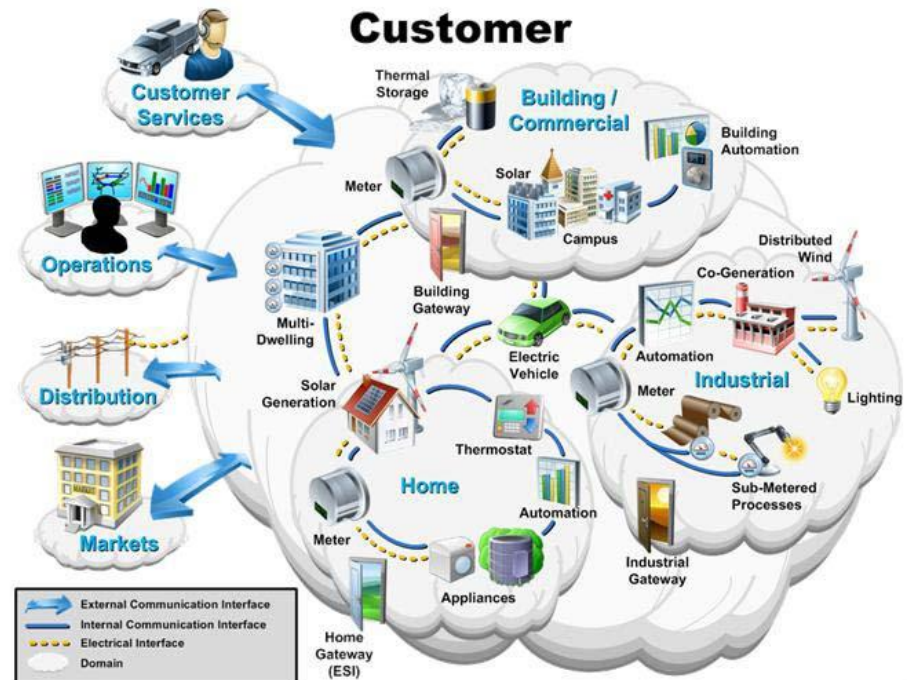
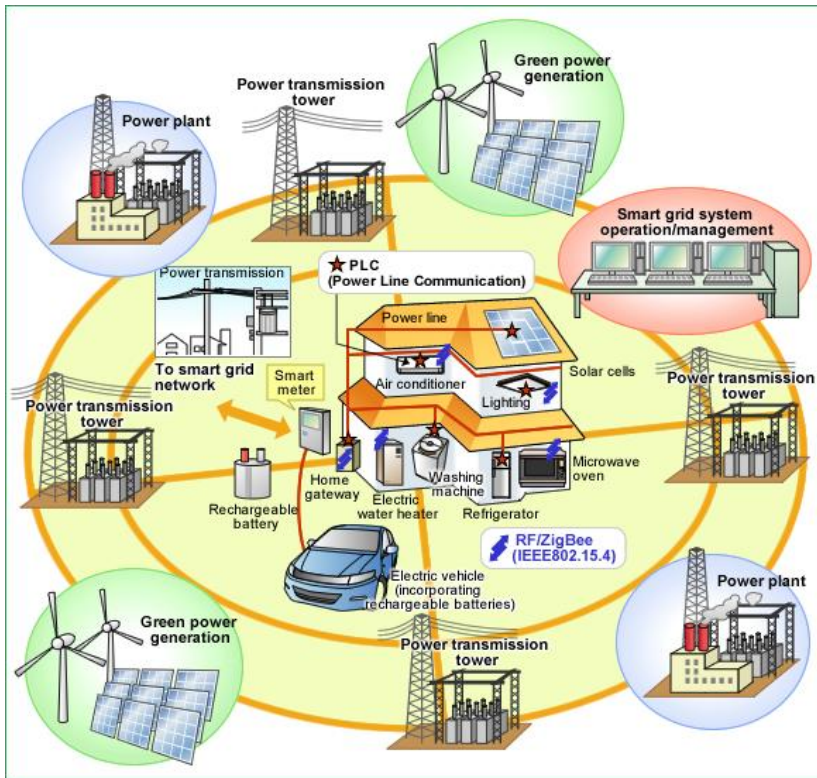
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The Smart Grid: Everybody can be User or Supplier



the smartness of the grid is supposed to organize all this!

- Supply and demand balanced at all times
- Maximum power not possible for all sources
- Traditional generating needed as fast backup
- At some point storage must be considered



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QUESTIONS?