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Welcome

Power reliability,

What do Power Quality, EMC and Lightning protection have in common?

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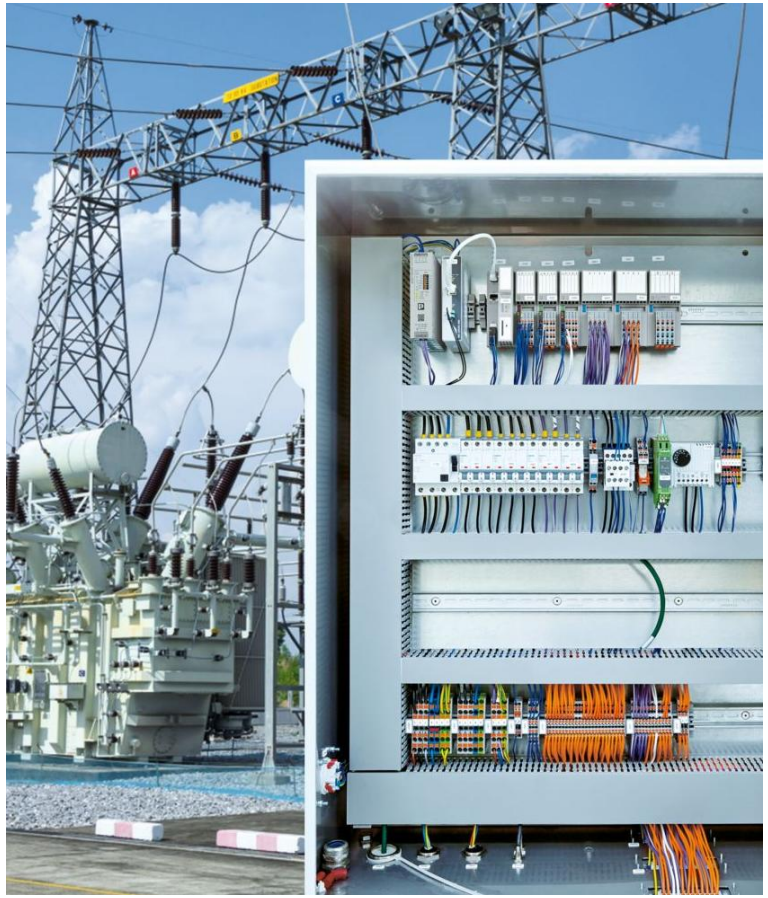
Power Electronics & Energy Storage event

Agenda

- Introduction
- Power Reliability/Quality?
- Industrial engineering, the challenge, simulatities
- Solution matrix
- Conclusion



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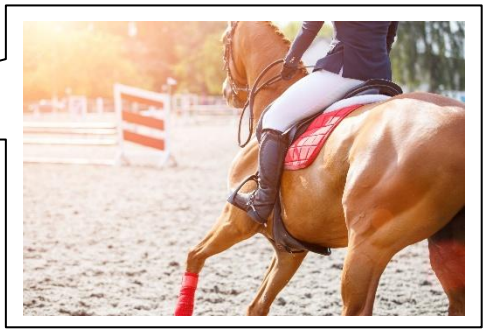
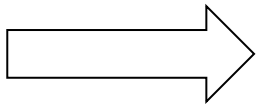
Introduction

Power reliability: power?

- Power is energy that is required to perform **labour**
- How much energy do we have availible?
  - Human => ~150W continue (1,2kW Peak)
  - Horse => ~750W continue (12kW Peak!)
  - Small buggy (400cc) => ~12kW continue (20kW Peak!!)





Introduction

Power reliability: power?

- Power is energy that is required to perform **labour**
- How much energy?

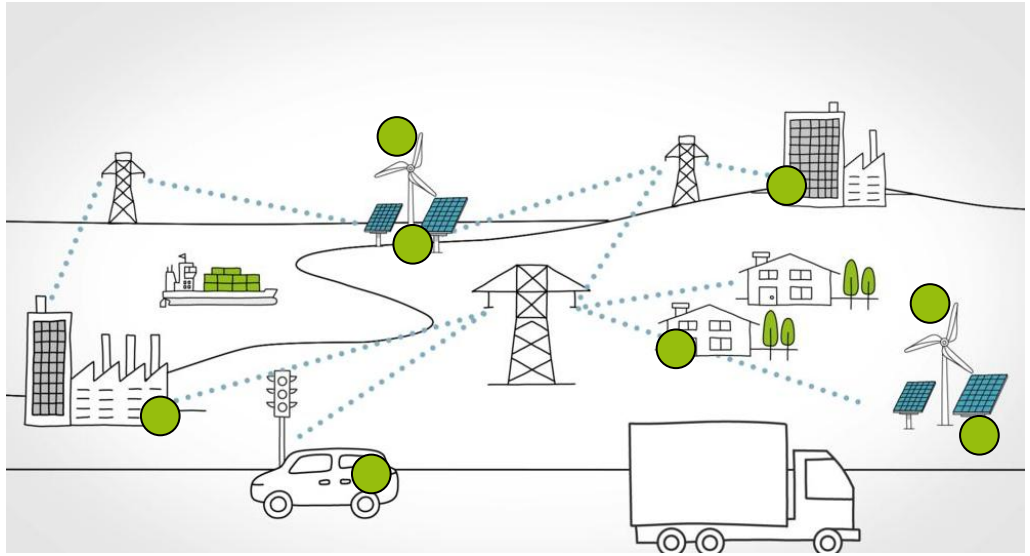
Fossil fuel: Large amounts of continuous, reliable power provides us:

Unprecedented possibilities!

Introduction

Power reliability: power?

- Today, most industrial processes **rely on electrical power**
- Renewable energy sources such as solar are abundant, but **not continuously available**
- This **requires energy management** and introduces new system risks.
- **Power electronics** needs for power regulation!



Electrical grids are becoming

increasingly inverter-dominated!

Power Reliability?

Power reliability: reliability? (quality?)

> *Reliability is the capability of a **system** or component to perform its required **functions** under stated **conditions** for a specific **period of time***

Definition example: Airport luggage handling	
the function?	Sorting system for Luggage at airport.
the environment?	Industrial with electrical disturbances, mechanical stress, and continuous operation 24/7.
the time scale?	Must tolerate up to 100ms power interruptions without loss of process data/mis-sorting
what constitutes a failure?	Loss of process data, misrouting luggage

*Source: IEEE and ISO.IEC 2010 p 297

Industrial engineering:

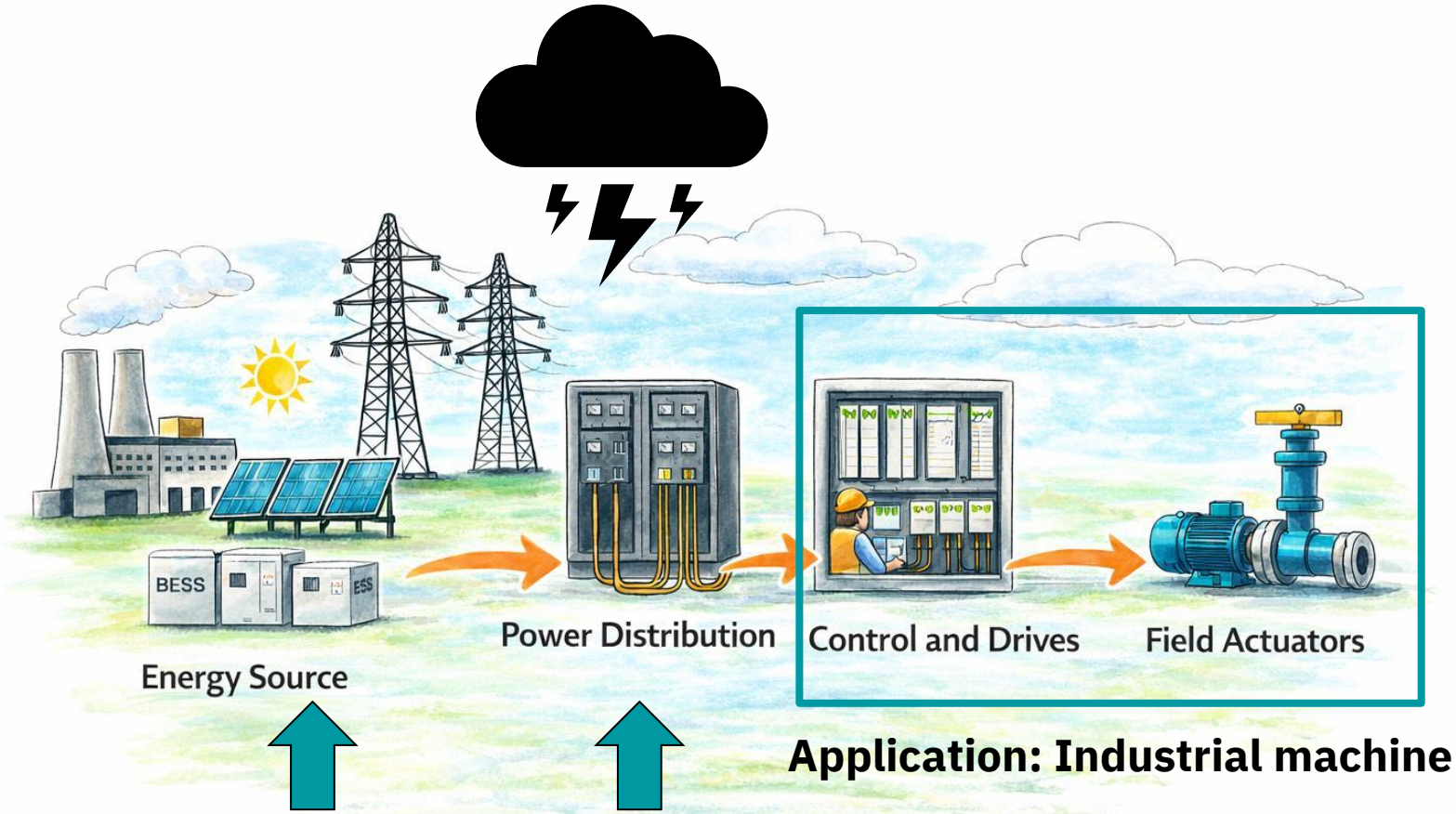
Aspect system: power delivery

- Focus on **Aspect system: Power delivery**
  - Power delivery of machine (sensor/actuators
  - Others are for example:
    - safety,
    - control,
    - Data/network,
    - remote access,
    - etc.
  - They can for sure influence each other.

Industrial engineering:

Industrial machine: energy supply chain

- The energy is supplied via a **'chain'** consisting of various links.
- According to tradition, a chain is only as strong as its **weakest link**.
- A disruption in the **source** influences the whole system
- External **interference** can cause disturbance on multiple links.

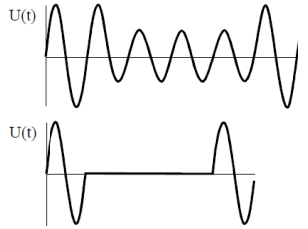


Industrial engineering:

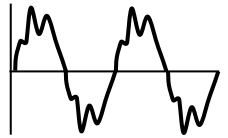
Aspect system: power supply

- **<u>Key for electrical power reliable power delivery:</u>**
  - **Availability** (trivial)
    - Sufficient power (capacity)
    - Continuity (NL: 99,999%)
  - **Power quality => Voltage!** (frequency)

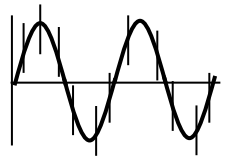
- **<u>3 main reliability issues:</u>**
  1. Voltage **fluctuations** (AC grid or 24VDC system)
     - engaging heavy AC/DC load.
     - grid failure



  2. Voltage **distortion** (harmonic distortion)
     - electronic load. (inverter, VFD, UPS)



  3. Voltage **transients** (spike voltages)
     - (switching, discharges, lightning)

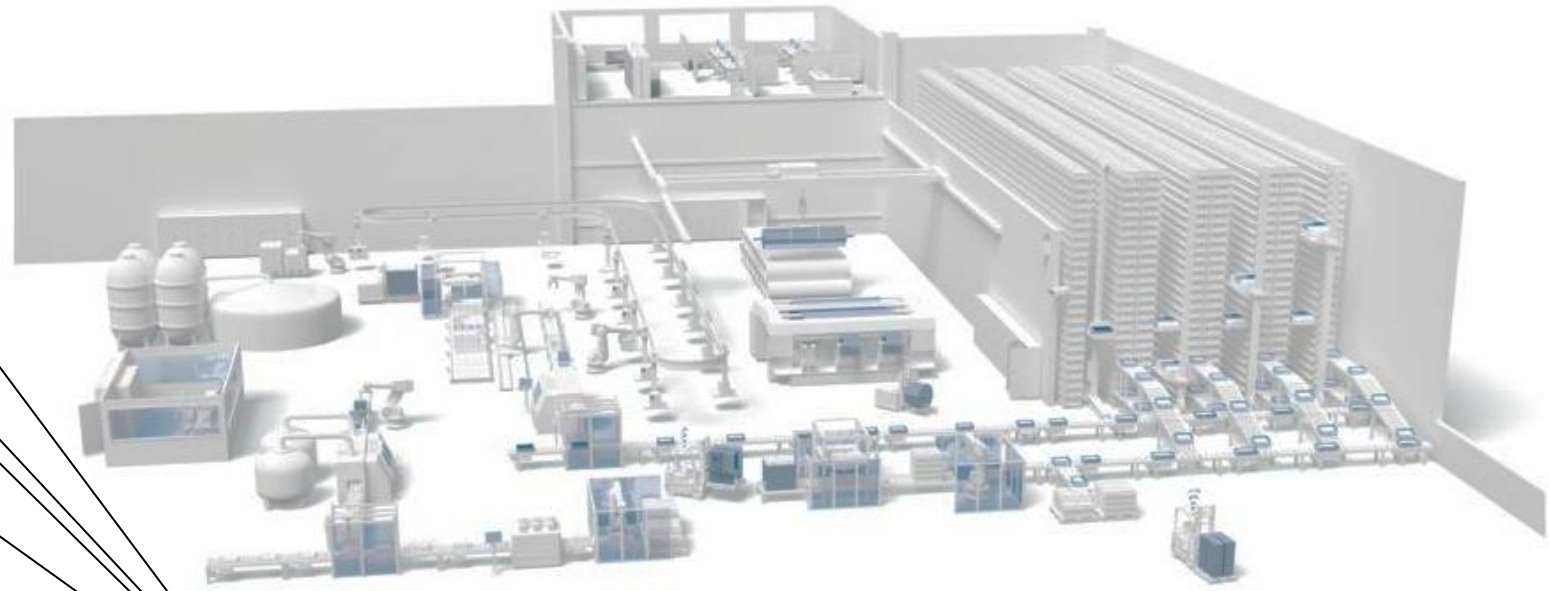


Industrial engineering

Industrial engineering

Design requirements for building an industrial machine

- Reliability
- Availability
- Maintainability
- Selectivity / error limitation
- Electrical Safety / Functional safety
- Fault tolerance / Resilience
- Thermal and electrical robustness
- Predictability / Transparency
- Extensibility / modularity



This requires architectural power measures!

Industrial engineering:

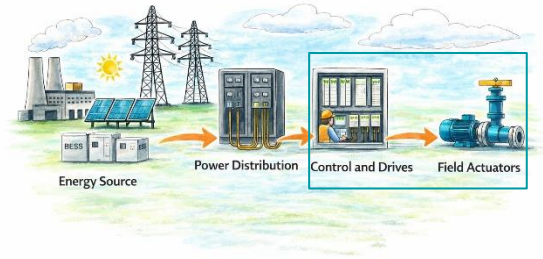
Construction demand vs construction solution

		Relia-bility	Availa-bility	Maintain-ability	Selectivity / error limitation	Safety	Resilience	Robust-ness	Predicta-bility	Modula-rity
	Selectivity (protection)	+++	+++	++	+++	++	++	++	++	+
1	**Segmentation & backup systems**	**+++**	**+++**	**++**	**+++**	**+++**	**+++**	**++**	**++**	**++**
2	**Redundancy (N+1, A/B)**	**+++**	**+++**	**++**	**+**	**++**	**+++**	**++**	**++**	**++**
	Safety coordination	+++	+++	++	+++	++	++	++	+++	+
3	**Grounding System**	**++**	**++**	**+**	**+**	**+++**	**++**	**++**	**++**	**+**
	Short-circuit resistance & dimensioning	+++	++	+	+	+++	+++	+++	++	+
	Isolation coordination / SPD	+++	++	+	+	+++	+++	+++	++	+
	Separation of circuits	++	++	+++	++	+++	++	++	+++	+++
	Fast fault detection & shutdown	+++	+++	++	+++	+++	++	++	+++	+
	Arc flash & security design	++	+	++	++	+++	+	++	++	+
	Standardization & classification	++	++	+++	+	++	++	++	+++	+++

0	no direct contribution
+	limited / indirect
++	relevant
+++	strongly decisive

Industrial engineering:

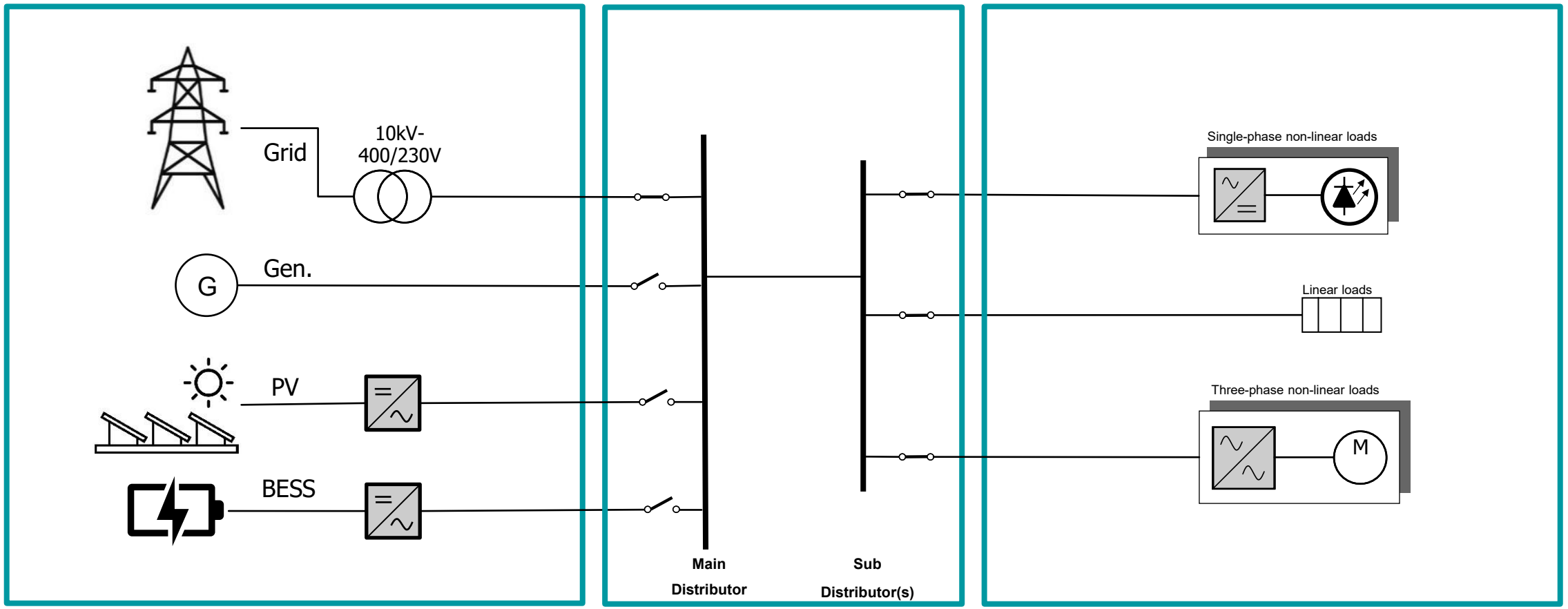
Example application



Energy sources

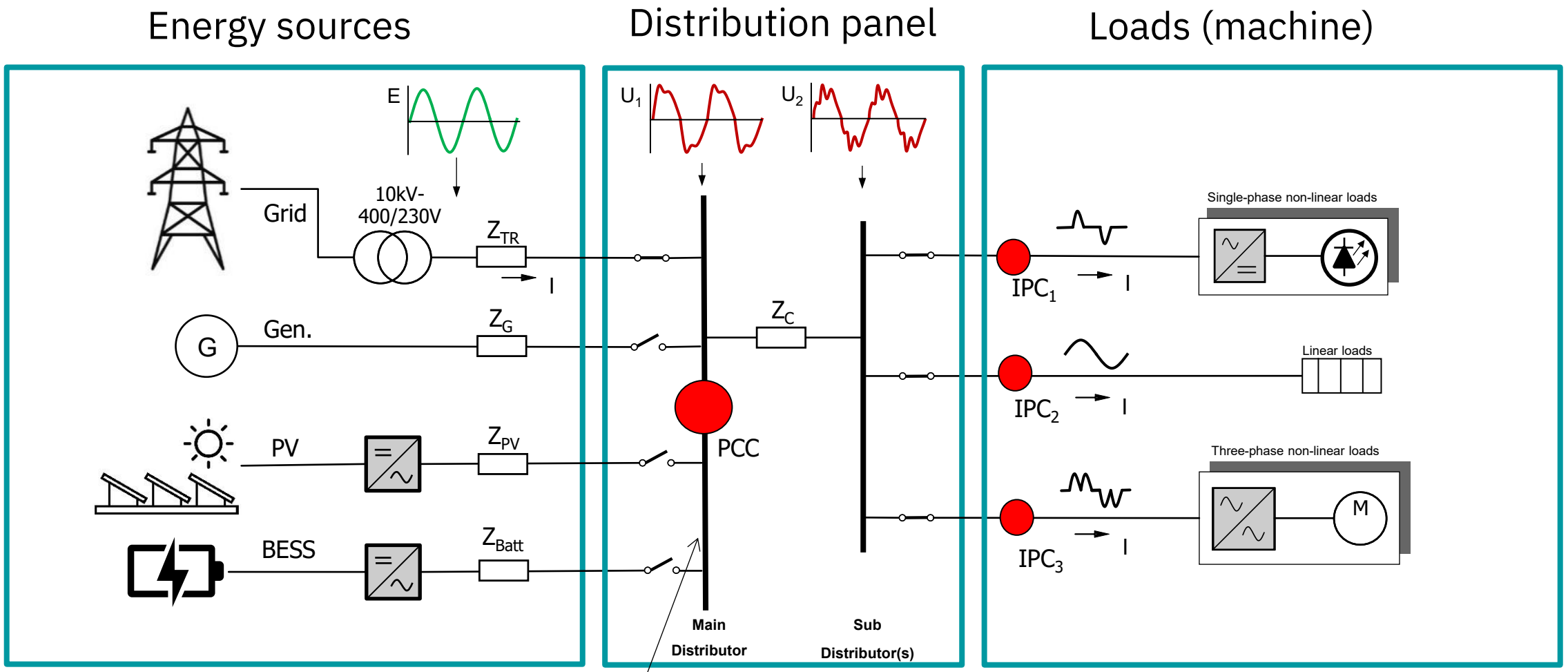
Distribution panel

Loads (machine)



Industrial engineering:

Segmentation : net impedance (2 harmonic voltage distortion)



$U_{PCC} = E - Z \cdot I$

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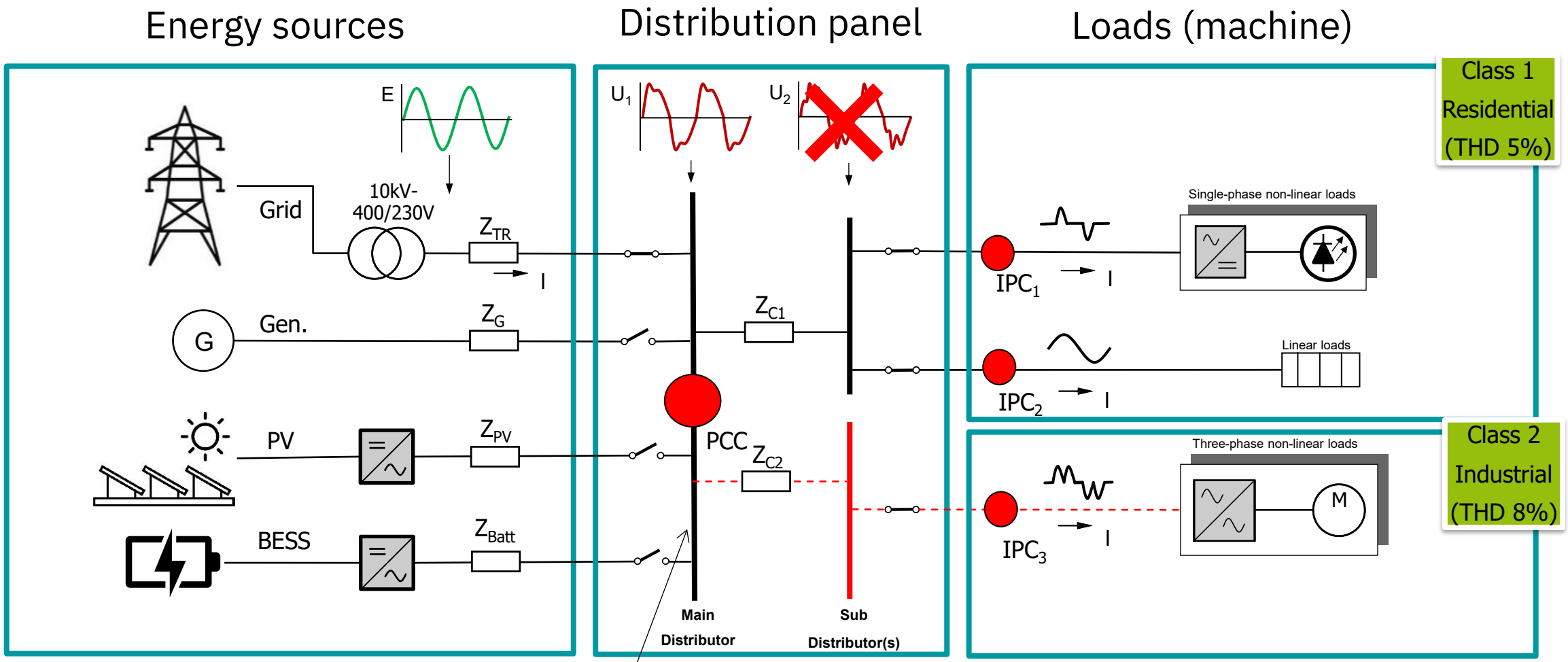
Industrial engineering:

Segmentation : net impedance (harmonic distortion)



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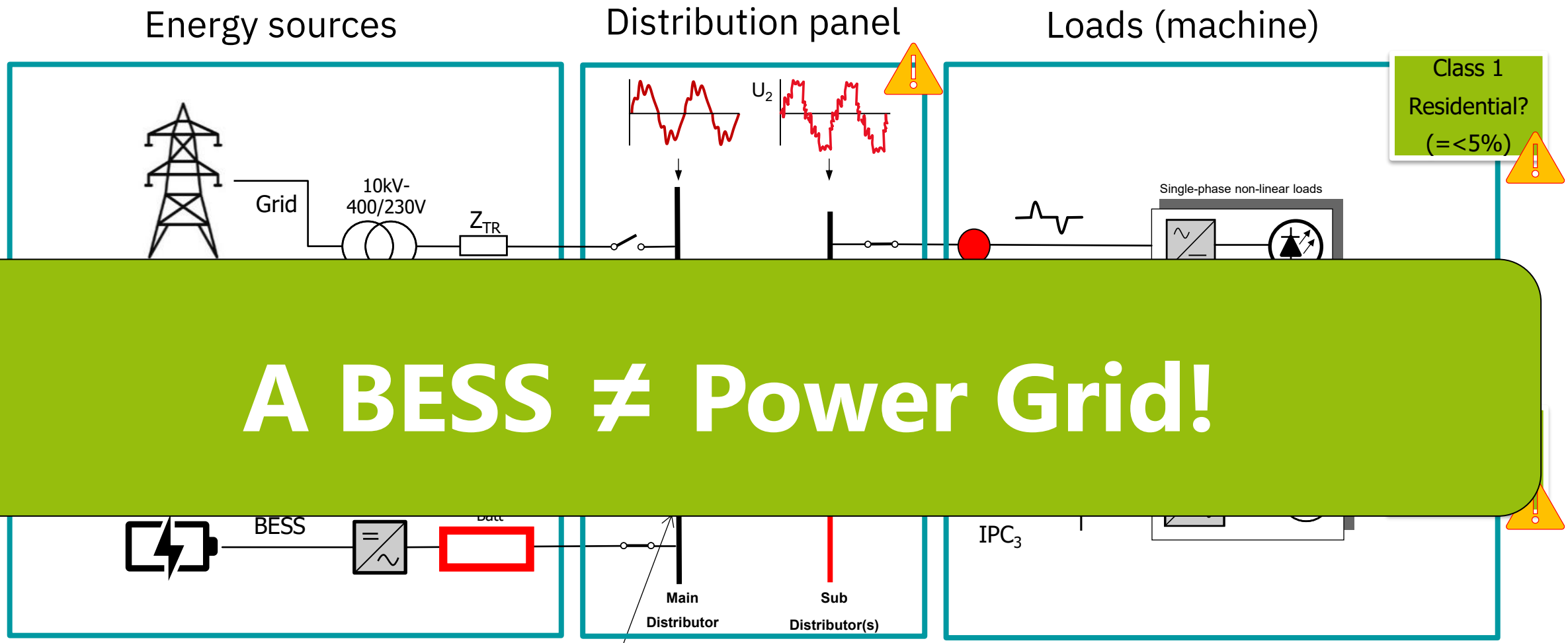

A BESS ≠ Power Grid!

$U_{PCC} = E - Z \cdot I$

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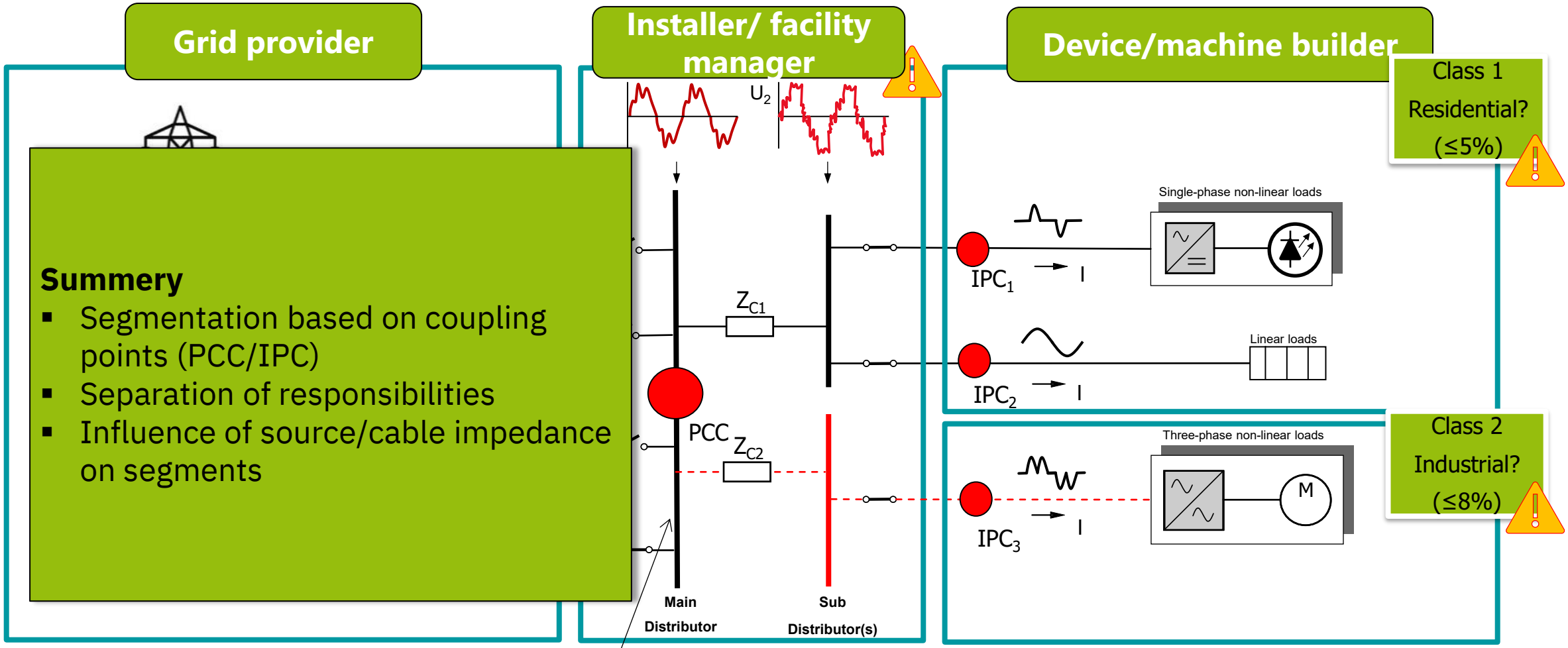
Industrial engineering:

Segmentation : net impedance (harmonic distortion)



$U_{PCC} = E - Z \cdot I$

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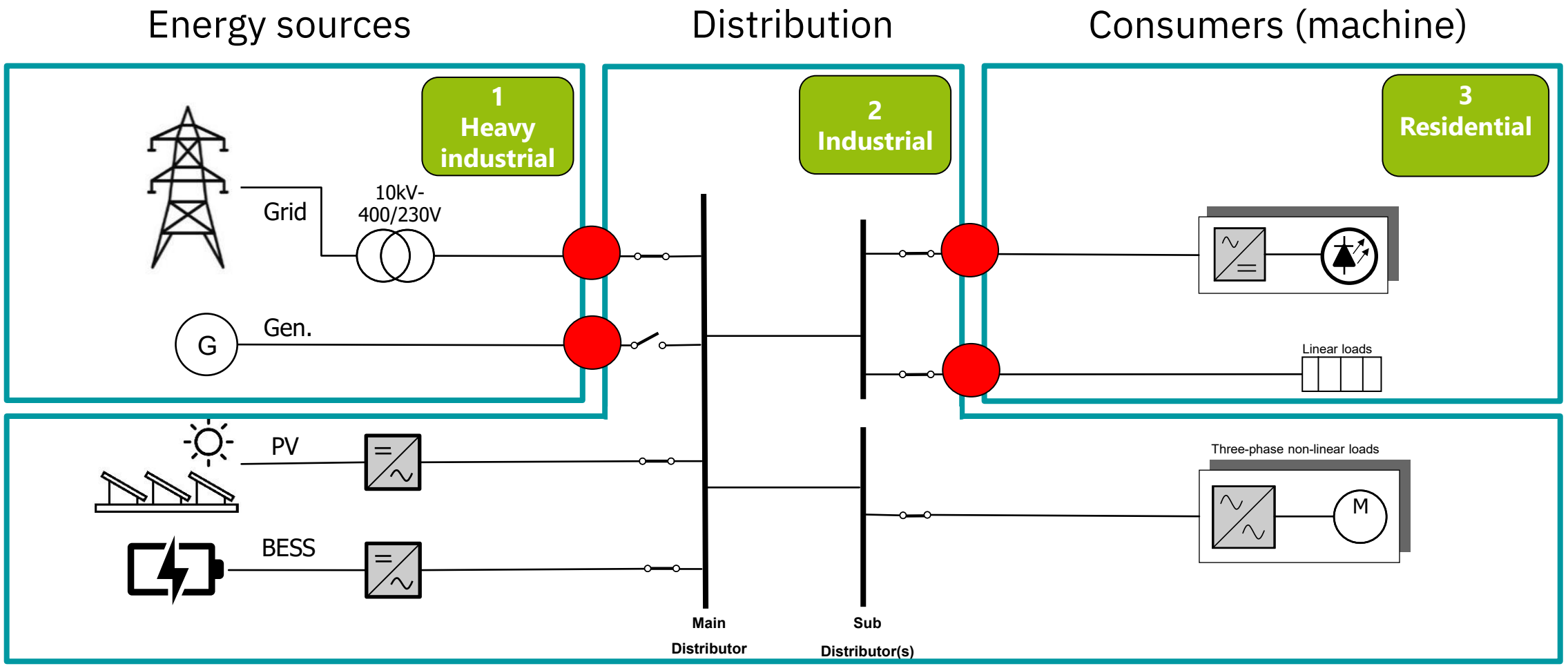
Industrial engineering:

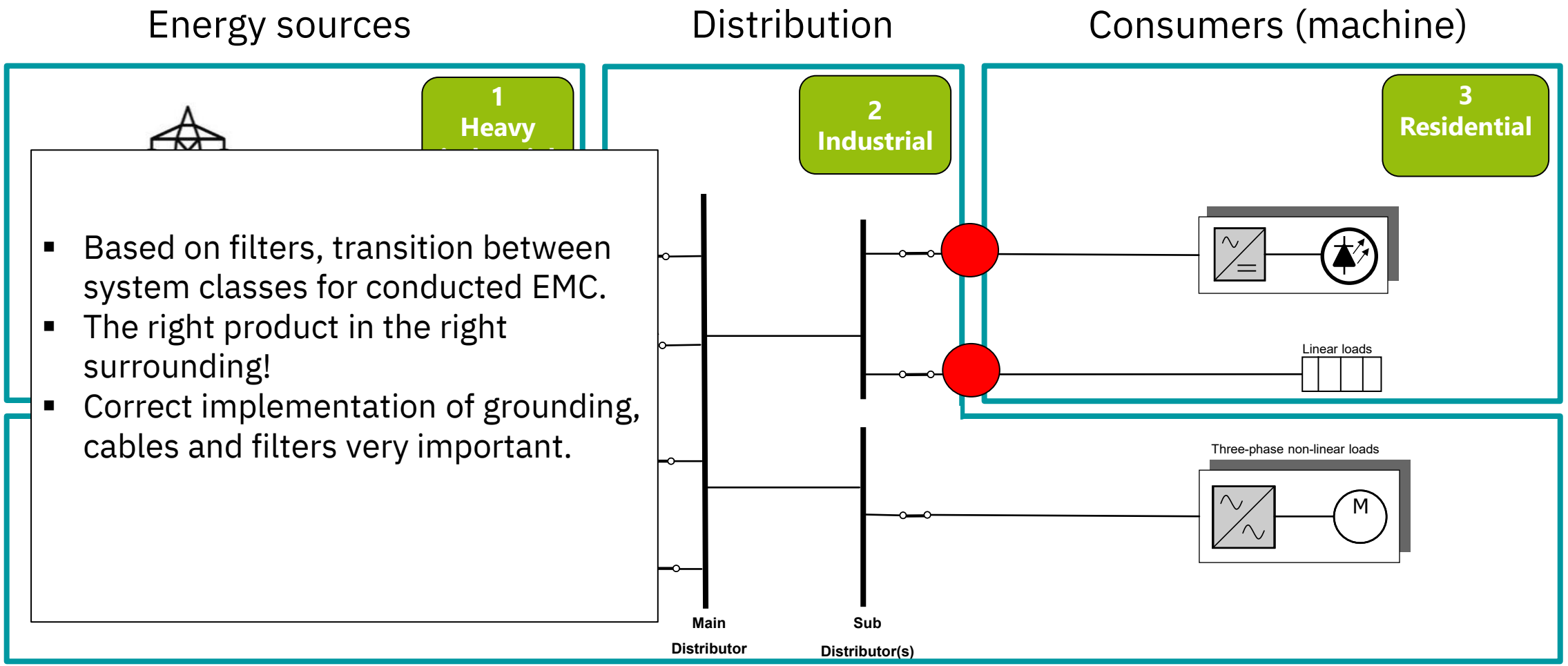
Segmentation : net impedance (harmonic distortion)

Impedance control	
Capabilities	- Reduced voltage drop and dips - **Improved EMC(PQ) performance** - Effective surge dissipation
Limitations	- Low impedance ≠ unlimited power - **HF and LF impedance differences**
Cost drivers	- **Copper volume** - Rail and grounding systems - Mechanical construction
Operational implications	- **Layout is decisive** - Later expansions are critical - Measuring ≠ easy
Impedance is not an abstract number, but material, length and geometry.	

Segmentation: EMC (3 Voltage transients)



Segmentation: EMC (3 Voltage transients)



- Based on filters, transition between system classes for conducted EMC.
- The right product in the right surrounding!
- Correct implementation of grounding, cables and filters very important.

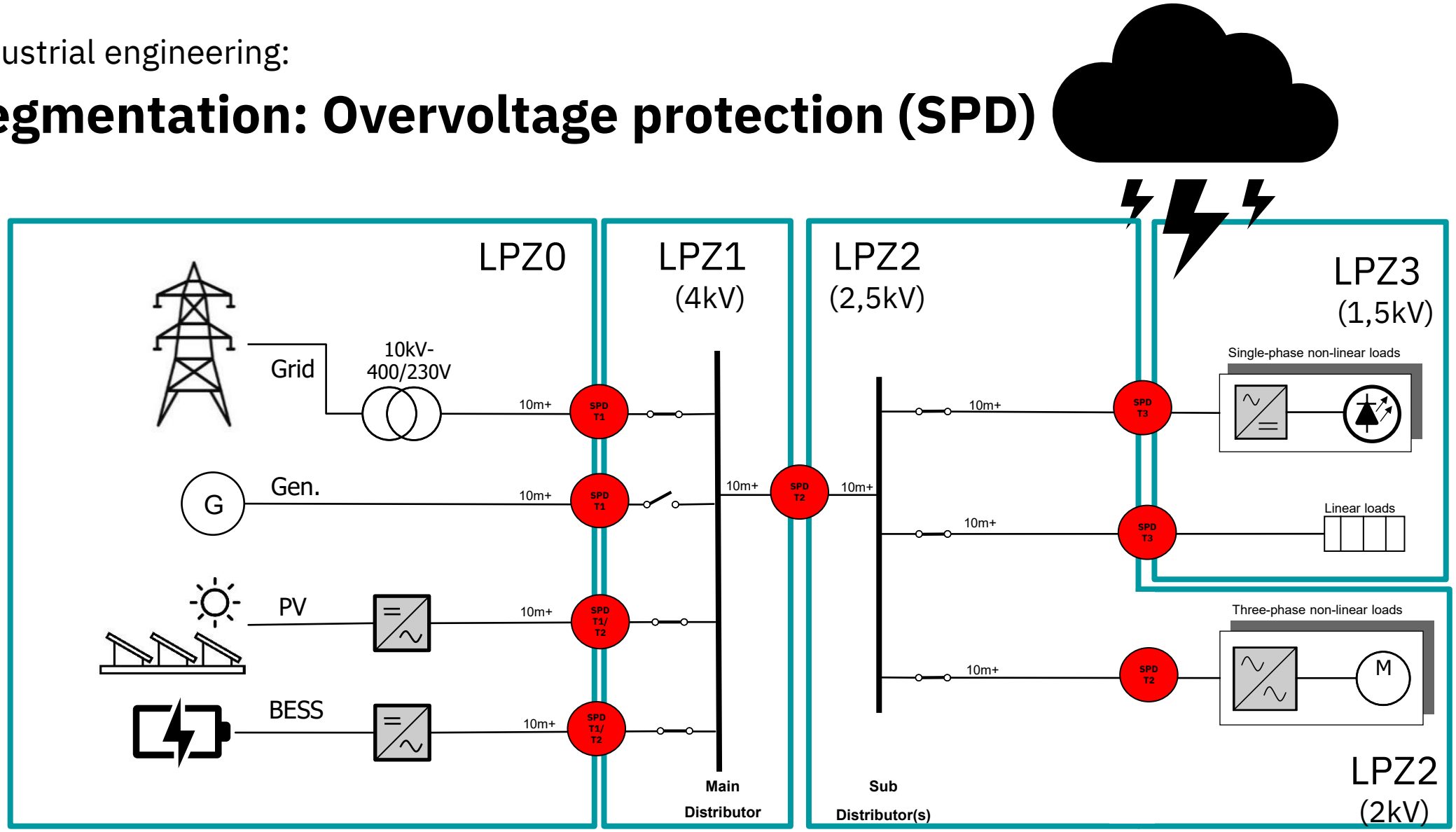
Industrial engineering:

Segmentation: EMC (3 Voltage transients)

Capabilities	• **Separation of source and victim** • Targeted filtering per segment • Impedance and structure control
Limitations	• Common-mode coupling via grounding • HF coupling (capacitative/radiation) • **Poor implementation (cable/shielding)**
Cost drivers	• EMC filters and chokes • **Shielding and cabling** • Separation via transformers
Operational implications	• Reduced error propagation between segments • Better protection of "clean" segments • **More reliance on grounding and layout**

Industrial engineering:

Segmentation: Overvoltage protection (SPD)



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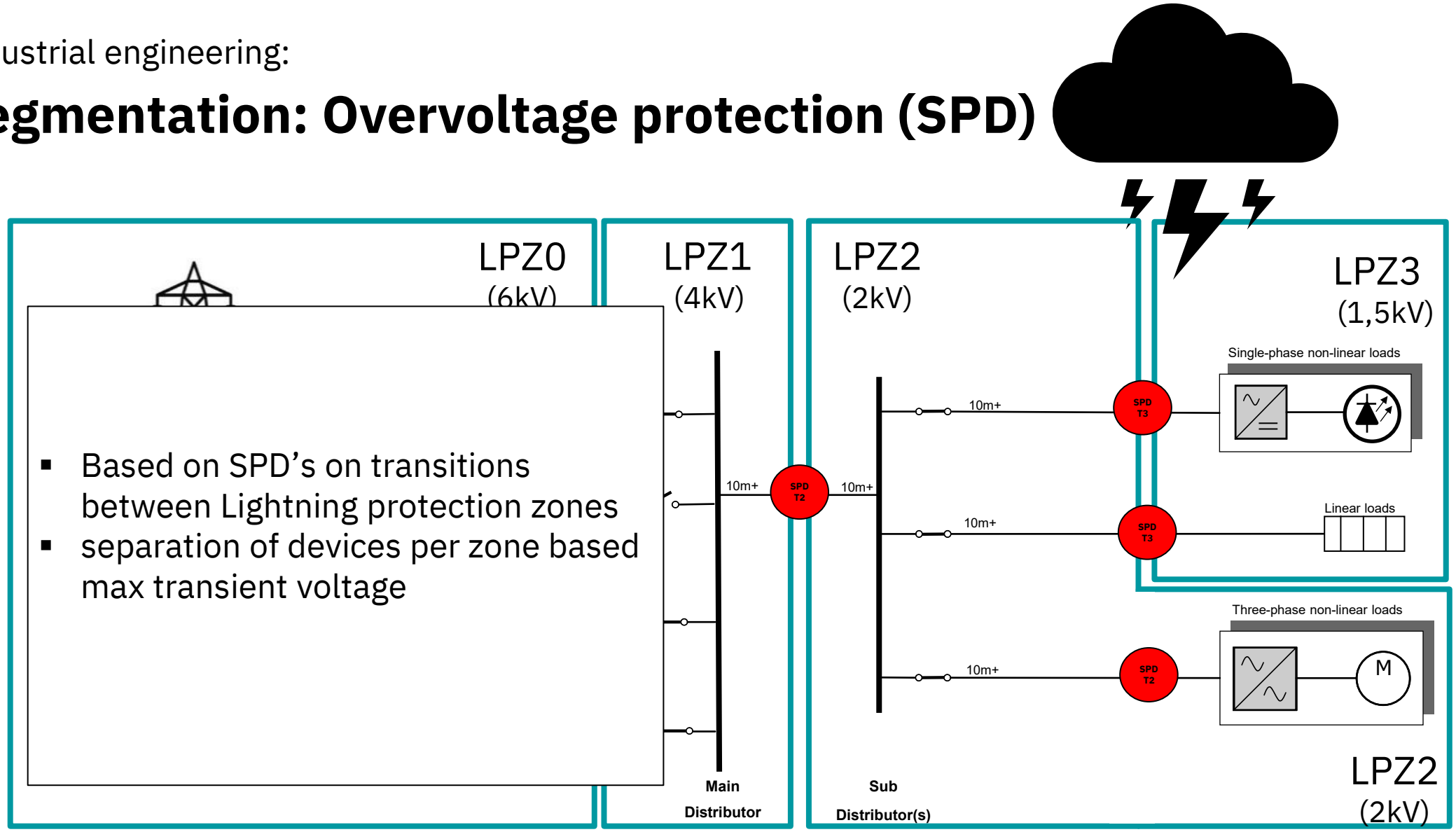
Industrial engineering:

Segmentation: Overvoltage protection (SPD)



- Based on SPD's on transitions between Lightning protection zones
- separation of devices per zone based max transient voltage

Industrial engineering:

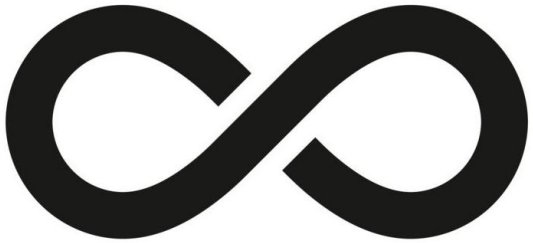
Overvoltage protection (SPD)

Capabilities	• **Targeted protection based on sensitivity** • Coordinated multi-stage protection at segment limit • Zone-/interface-thinking (LPZ-principle)
Limitations	• Installation inductance/distance → higher residual voltage • **SPD's Relegation (wear and tear)** • Internal transients remain locally dominant
Cost drivers	• **Number of segment boundaries** • Type choice & energy class (Type 1/2/3) • Installation requirements (wiring/pre-protection/mounting)
Operational implications	• **Less downtime/damage => higher availability** • Segment boundaries become "critical nodes" • The design will be traceable to the LPZ concept (IEC 62305)

Conclusion

	Redundant power supplies	UPS / DC-UPS	Protection coordination	Layered SPDs	Filters / reactors / (harmonic mitigation)	Segmentation (clean/dirty power)	Grounding / bonding / shielding	Derating / overdimensionering	Hot swap / modularity / bypass	Monitoring / condition monitoring	FMEA/SPOF analysis
Reliability	++	+	+	+	+	++	++	**+++**	+	+	++
Availability	**+++**	**+++**	++	++	+	++	++	++	++	++	++
Maintainability	+	+	++	+	0	+	0	+	**+++**	**+++**	++
Selectivity	0	0	**+++**	0	0	+	0	0	0	+	+
Voltage quality	+	++	+	++	**+++**	++	++	+	0	+	+
EMC immunity	+	+	0	**+++**	++	**+++**	**+++**	+	0	+	+
Electrical Safety	++	++	**+++**	++	+	++	**+++**	++	+	++	**+++**
Fault tolerance	**+++**	++	+	+	0	+	+	+	+	+	++
Predictability	+	+	+	0	0	+	+	0	++	**+++**	++
Extensibility	+	0	0	0	0	+	0	+	**+++**	+	+

0	**hardly any direct influence**
+	**limited positive influence**
++	**clear positive influence**
+++	**very strong positive influence**



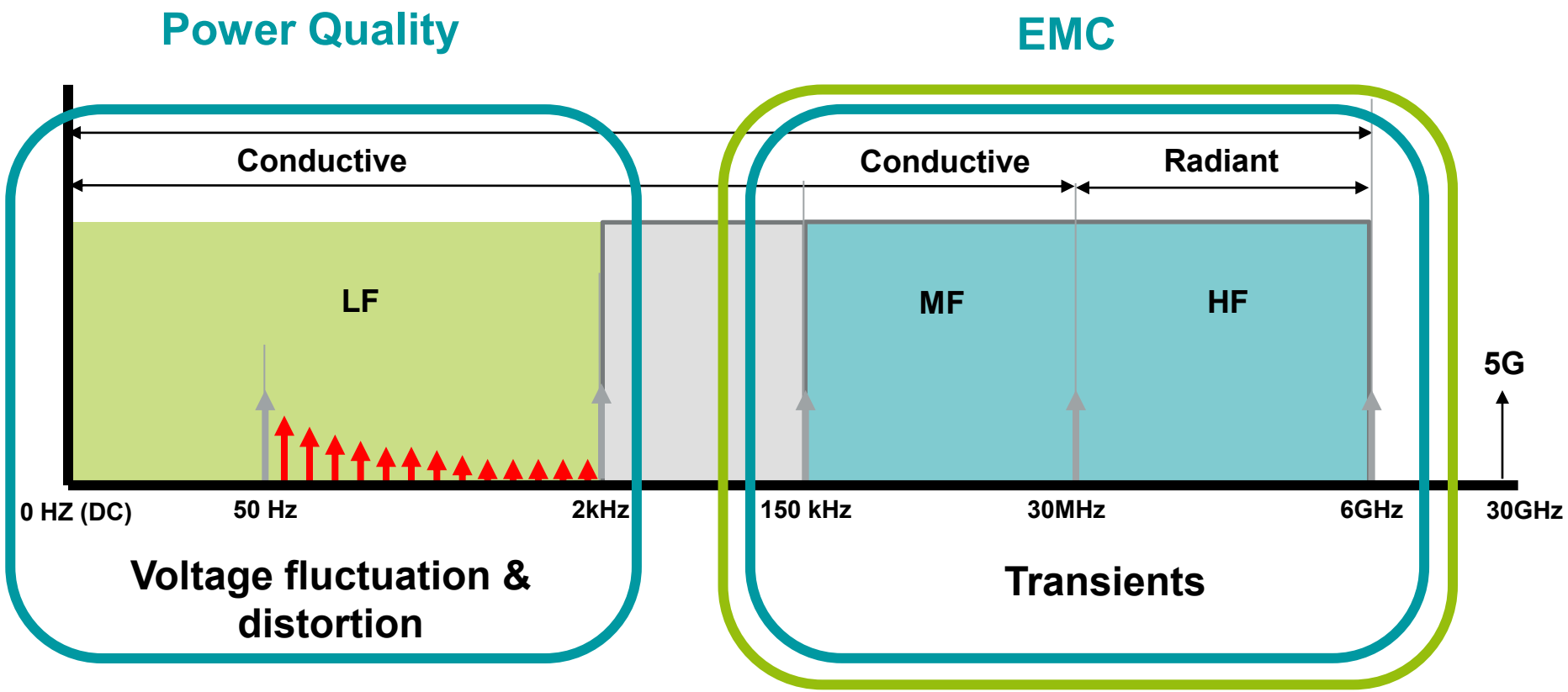
Power Reliability

It is <u>not</u> a **product property**.

It is a coherence of design choices, physical boundaries and operational discipline

Conclusion

Guidance by standards: ElectroMagnetic Compatibility guideline



Lightning and overvoltage protection

Contact

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