FUEL CELL FOR HIGH POWER QUALITY APPLICATIONS

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What is Power Quality

- "The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment"
- "Good" power quality is whatever electrical supply necessary for end-use to perform its intended function(s)
- Safety is a key issue and is an overriding factor

PQ Dimensions

- **Supply continuity (Number and duration of interrruptions)**
- **Voltage waveform (magnitude, frequency, harmonic distortion, symmetry)**

- Commercial quality (technical support in terms of timeliness and competence, pricing, contract policies, energy services such as DSM and demand response)

Power system constraints

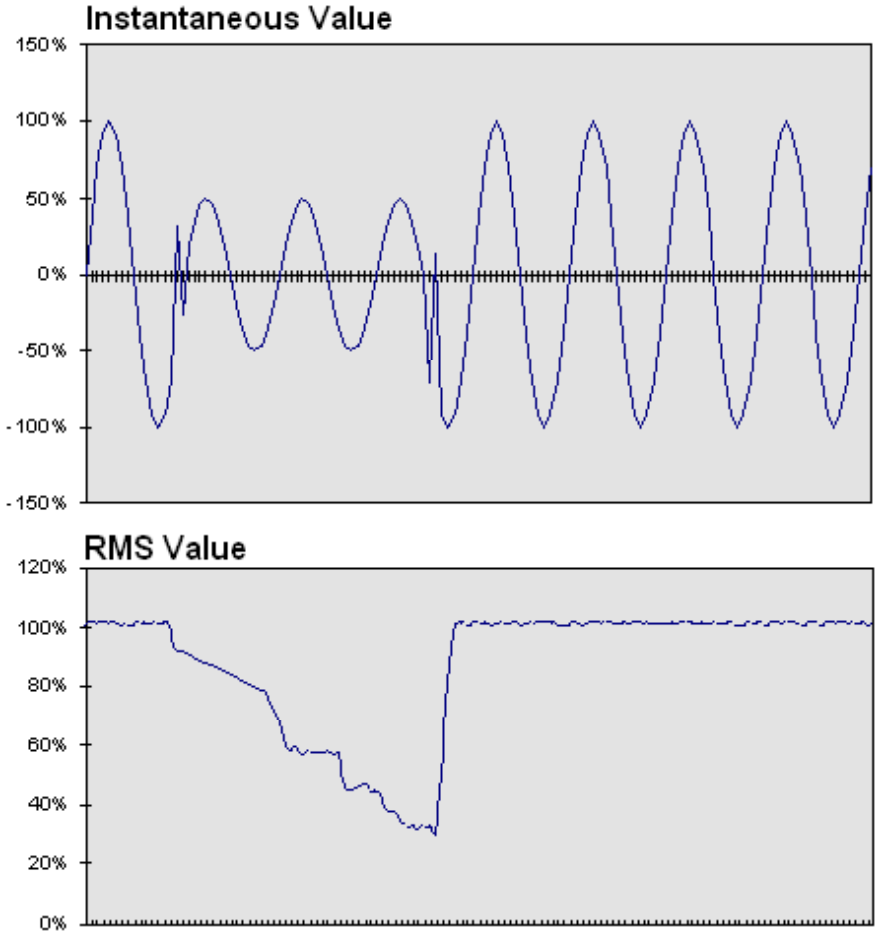
- Random external factors
  - Weather
  - Human activities
  - Animals
  - Vegetation
- Increasing share of non-linear loads
- Increasing demand for high PQ

Main PQ problems

- **Voltage sags**
- **Micro-interruptions**
- **Long interruptions**
- Voltage spikes
- Voltage swells
- Voltage fluctuations
- Voltage unbalance
- Noise
- Harmonic distortion

Voltage Sags

A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute.



Causes:

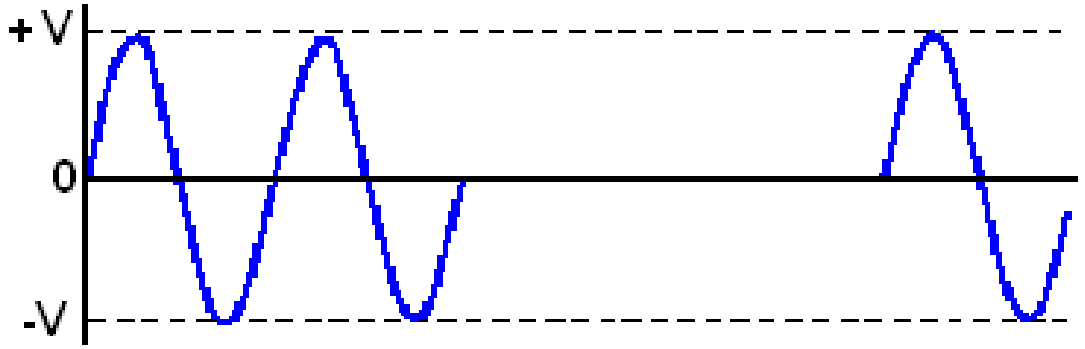
- Faults on the transmission or distribution network.
- Faults in consumer's installation.
- Connection of heavy loads and start-up of large motors.

Consequences:

- Malfunction of microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage.
- Tripping of contactors and electromechanical relays.
- Disconnection and loss of efficiency in electric rotating machines.

Micro-Interruptions

Total interruption of electrical supply for duration from few milliseconds to one or two seconds.



Causes:

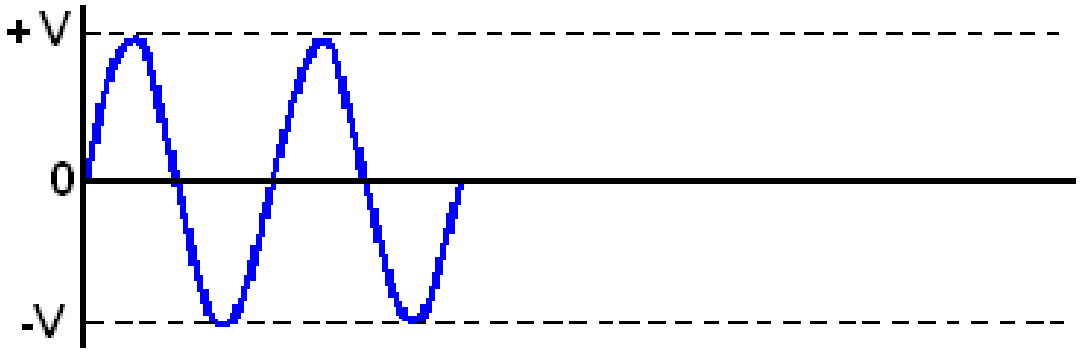
- Opening and automatic reclosure of protection devices.
- Insulation failure, lightning and insulator flashover.

Consequences:

- Tripping of protection devices.
- Loss of information and malfunction of data processing equipment.
- Stoppage of sensitive equipment (such as ASDs, PCs, PLCs).

Long Interruptions

Total interruption of electrical supply for duration greater than 1 to 2 seconds.



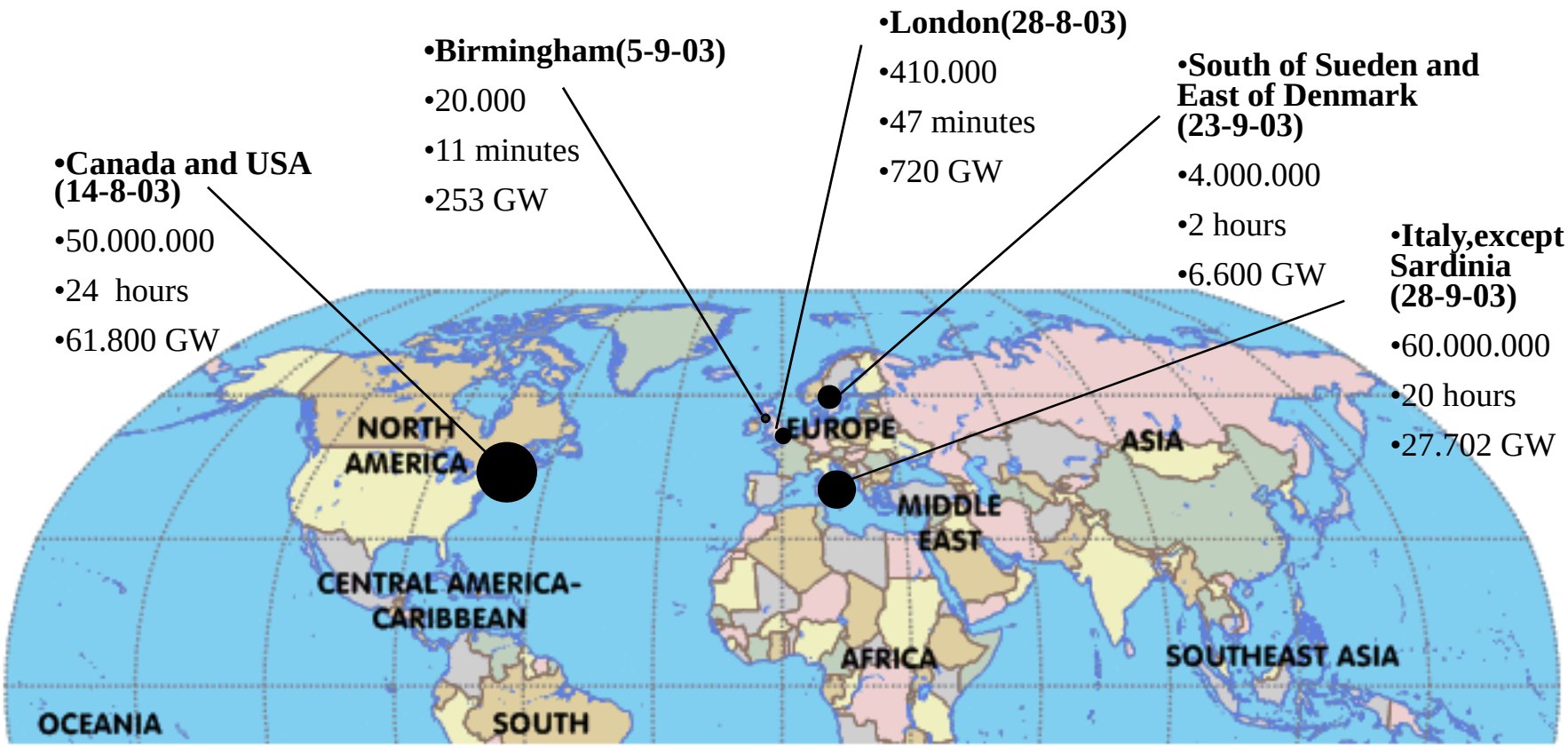
Causes:

- Equipment failure in the power system network.
- Storms and objects (trees, cars, etc) striking lines or poles, fire.
- Human error, bad coordination or failure of protection devices.

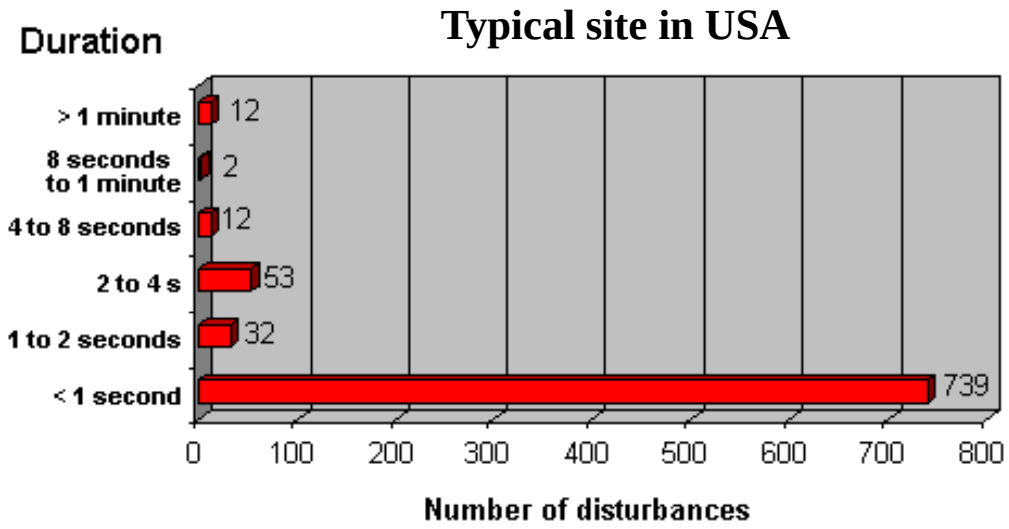
Consequences:

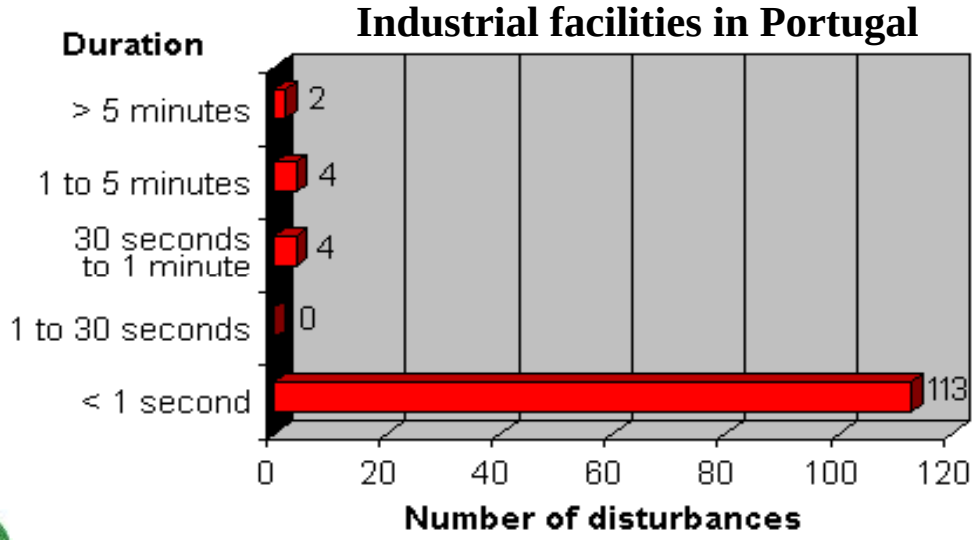
- Stoppage of all equipment.

Long Interruptions (2003)



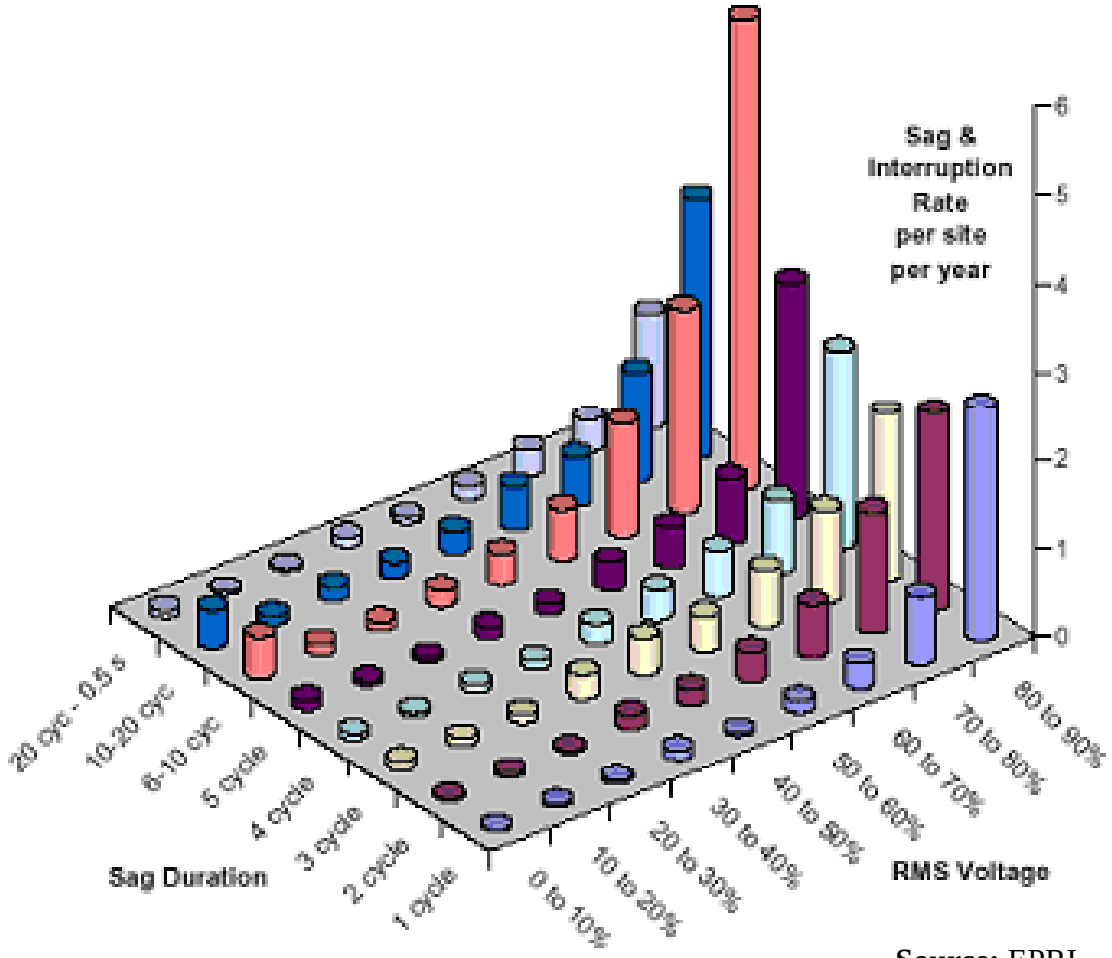
Power Quality characterization





In both cases, about 90 % of PQ events have duration below 1 second.

Power Quality characterization



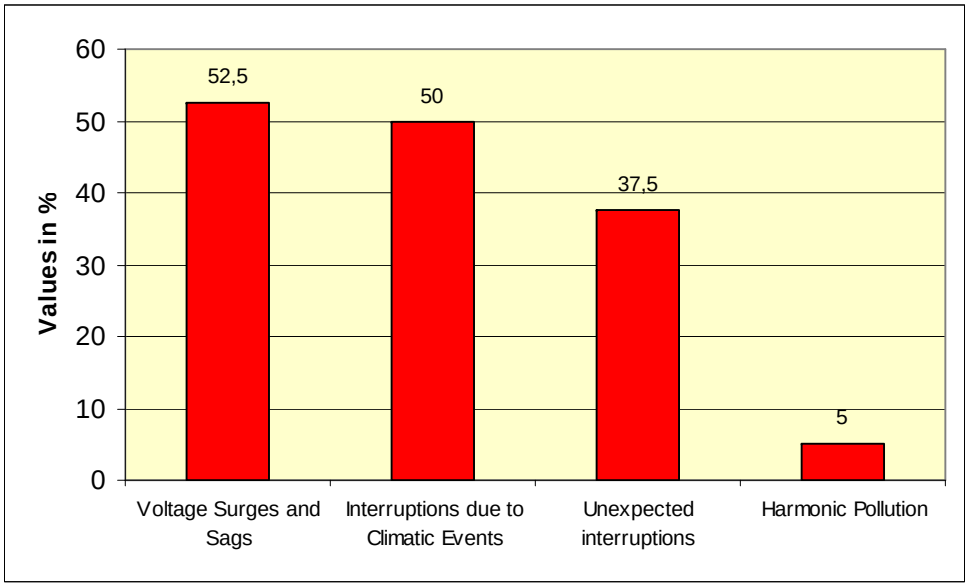
Source: EPRI

92% of PQ disturbances were voltage sags with amplitude drops up to 50% and duration below 2 seconds.

Survey about the perception of Power Quality related problems in Portugal

➔ 57 % of the inquired companies have PQ complaints, although with quite significant differences between sectors.

➔ Sectors with more complaints, are: Automotive, Pulp and Paper, Stone, Wood and Furniture, Ceramics, Glass and Cement Industries and Plastics and Textiles.



Power quality problems observed.

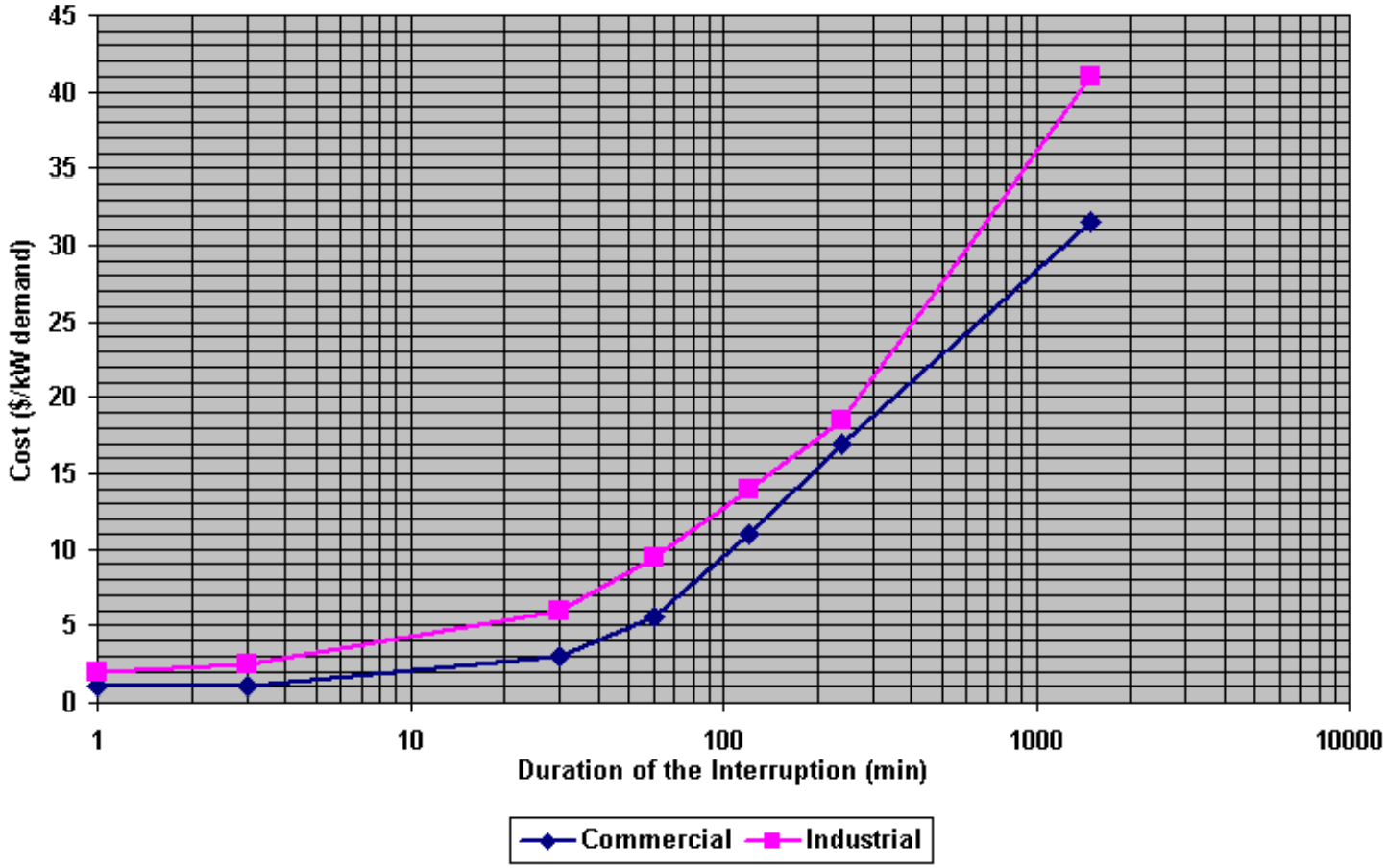
- **We should highlight the low values obtained regarding <u>Harmonic Pollution</u>, in spite of the real impact of disturbances caused by non linear loads and harmonics, if we take into account the character of the loads in the facilities.**

Power Quality costs

- **Business Week (1991)** - 26,000 million USD per year in the United States
- **EPRI (1994)** - 400,000 million USD per year in the United States.
- **US Department of Energy (1995)** - 150,000 million USD per year for United States.
- **Fortune Magazine (1998)** - Around 10,000 million USD per year in United States.
- **E Source (2001**) - 60,000 to 80,000 USD per installation, per year for continuous process industries, financial services and food processing in the United States.
- **European Copper Institute (2001)** - 10,000 million EUR per year, in EU in industry and commerce.

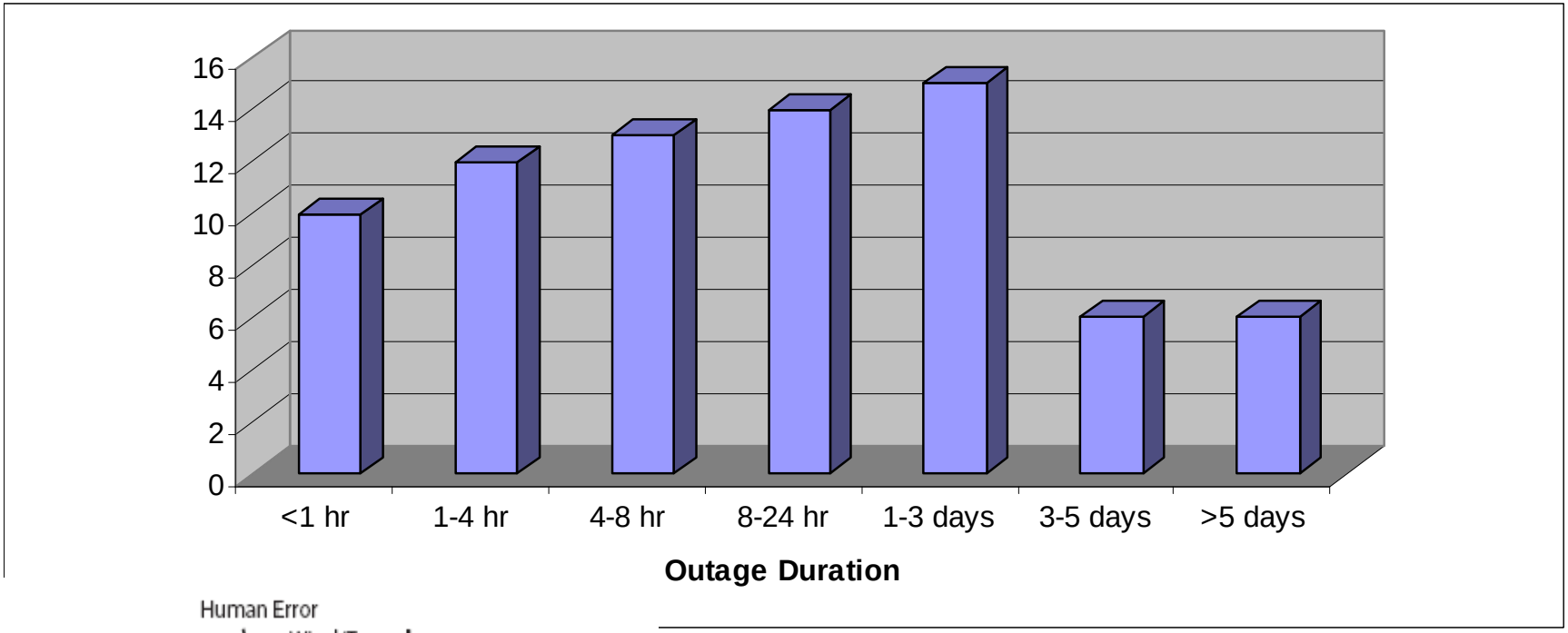
Power Quality costs

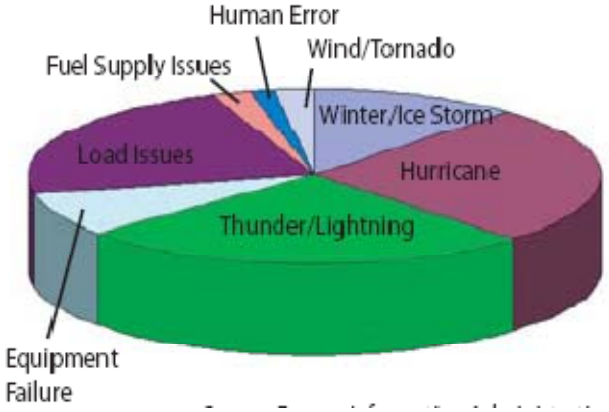
Costs of interruptions vs. duration



Source: Electrotek Concepts

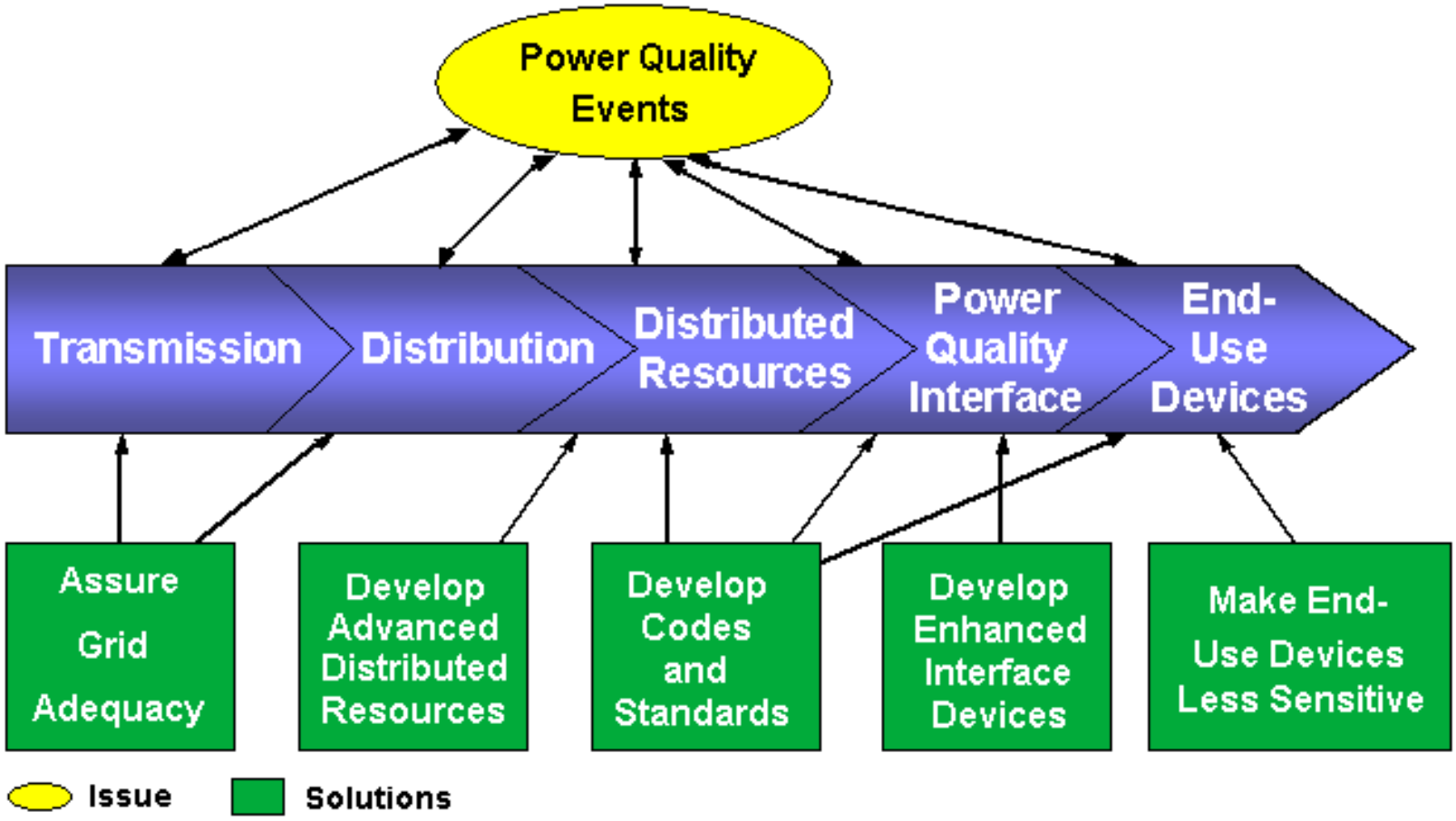
2007 Major Power Grid Disturbances in the US
> 50 Mega Watts





Energy Information Administration
Official Energy Statistics from the U.S. Government

Power Quality solutions



Codes and Standards

Need to regulate:

- the minimum PQ level that utilities have to provide to consumers, and the immunity level that equipment should have.

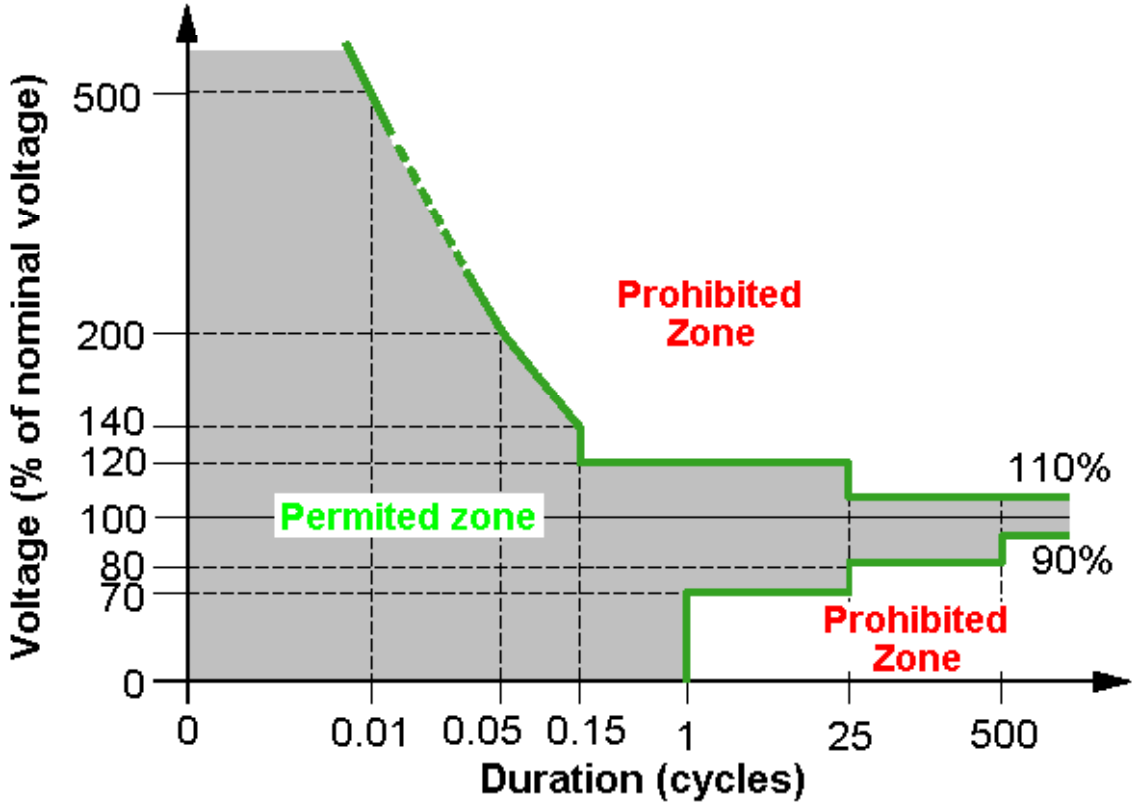
Most relevant standards:

- CBEMA curve
- ITIC curve
- IEC 61000
- EN 50160

ITIC curve

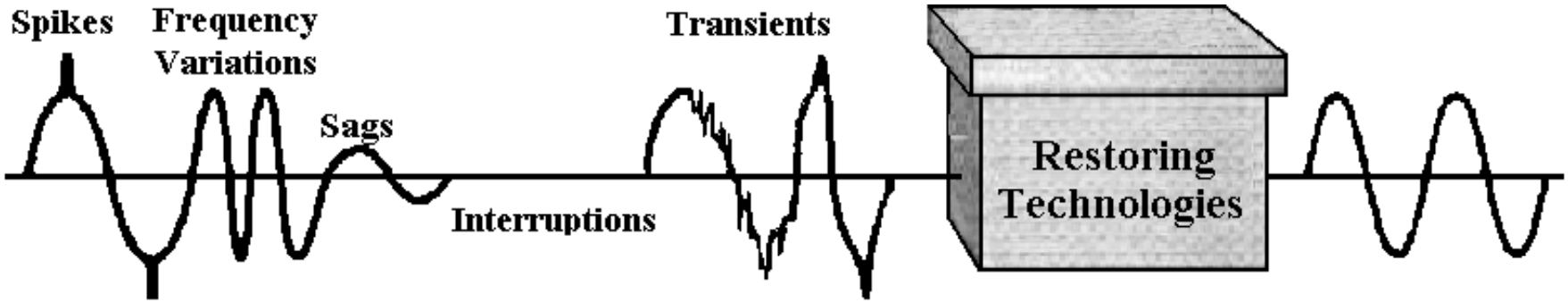
ITIC – Information Technology Industry Council (1996, revised 2000).

Specifies the maximum and minimum limits that sensitive electronic equipment should be able to withstand.

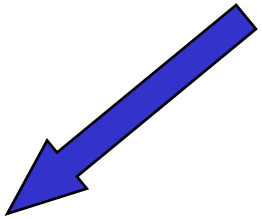


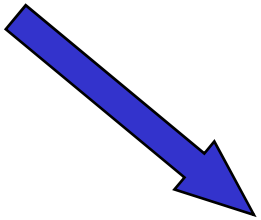
Restoring technologies

Restoring technologies are used to provide the electric loads with ride-through capability in poor PQ environment.



Distributed Resources





Distributed Generation (DG)

- Reciprocating engines
- Microturbines
- **Fuel Cells**

Energy Storage (restoring technologies)

- Electrochemical batteries
- Flywheels
- **Supercapacitors**
- SMES
- Compressed air

Distributed Generation

• Used to provide “clean power” to critical loads, isolating them from disturbances with origin in the grid.

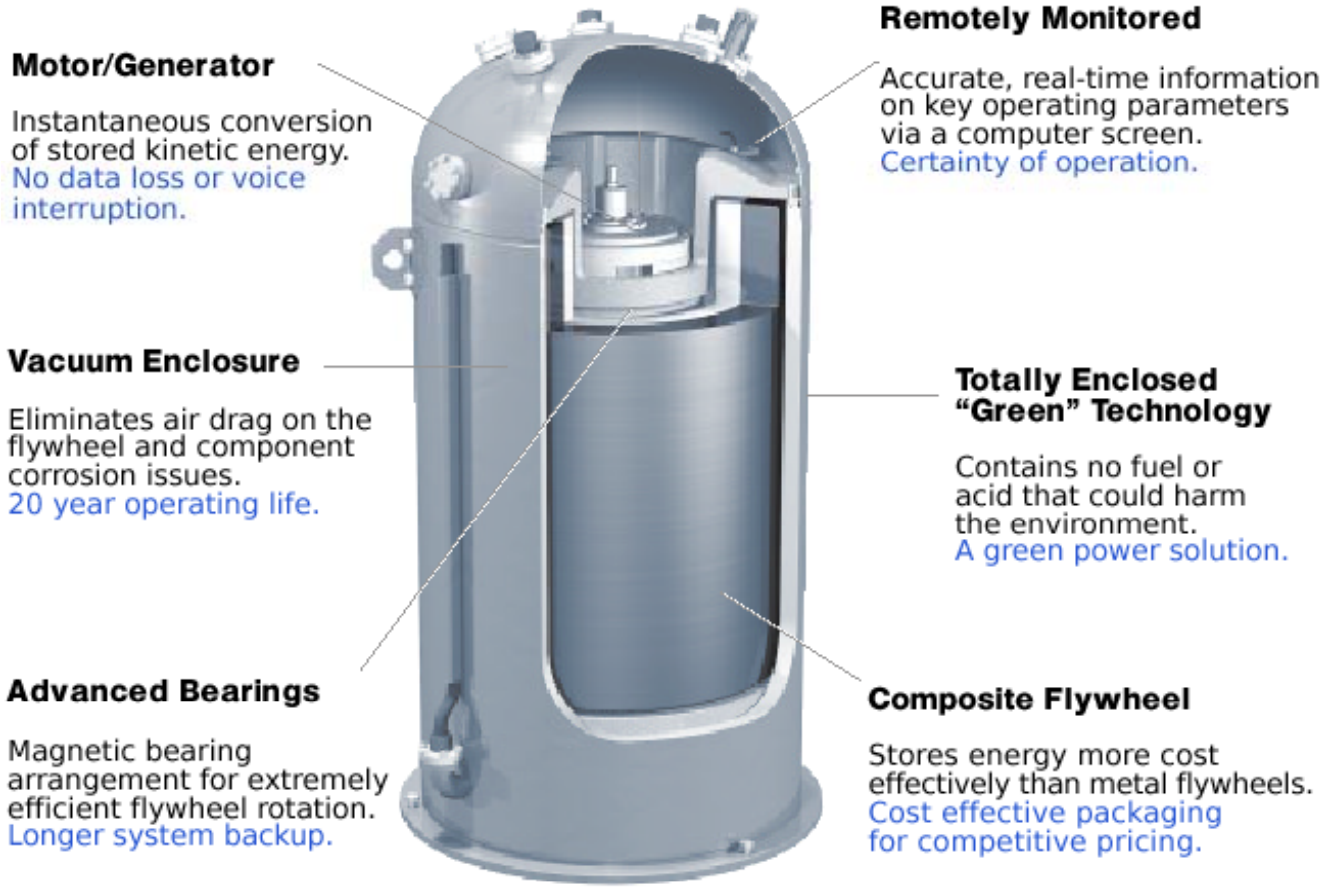
• Backup generators to assure energy supply to critical loads during sustained outages.

	Reciprocating Engines	Microturbines	Fuel Cells
Timing	• Ongoing	• Emerging now	• Mid-2000’s
Market	• Standby/backup utilization	• Peak-shaving and PQ	• Prime power and PQ
Economics	• 300 a 600 $/kW	• 750 $/kW	• 1000* a 4000 $/kW
	• 33-45% efficient	• 20-30% efficient	• 45-60% efficient
	• <5% utilization	• ~20% utilization	• >80% utilization
	• 15-30 cents/kWh	• 10-15 cents/kWh	• 5*-15 cents/kWh

* **predicted**

Flywheels

Electromechanical device that couples a rotating electric machine (motor/generator) with a rotating mass to store energy for short durations.

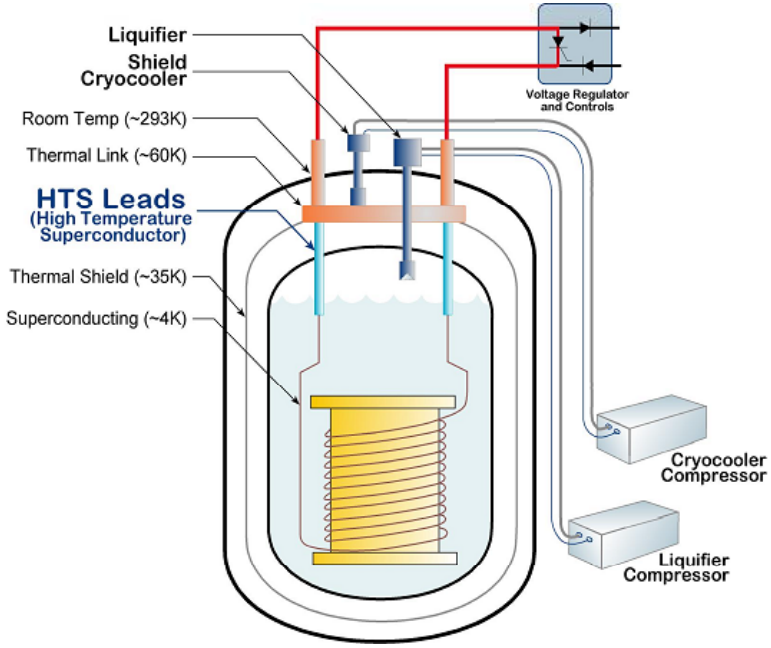


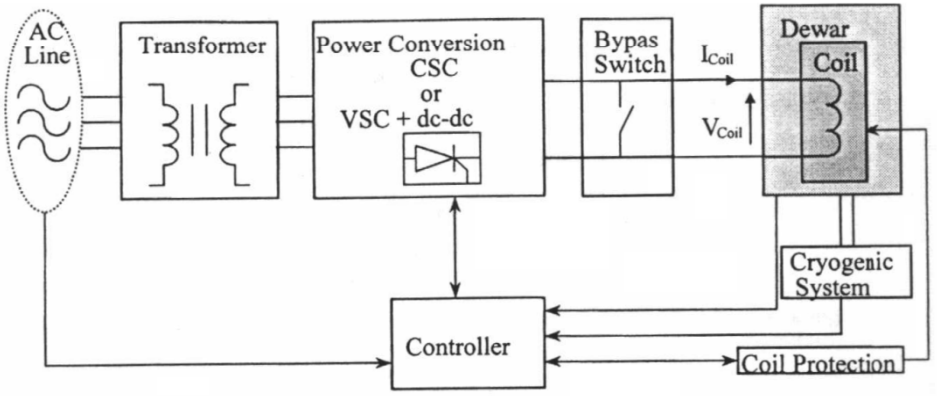
Source: http://www.beaconpower.com

Superconducting Magnetic Energy Storage (SMES)

Energy is stored in the magnetic field of a coil made of superconductor material.

- High power density
- Very fast response
- Very expensive (on development)

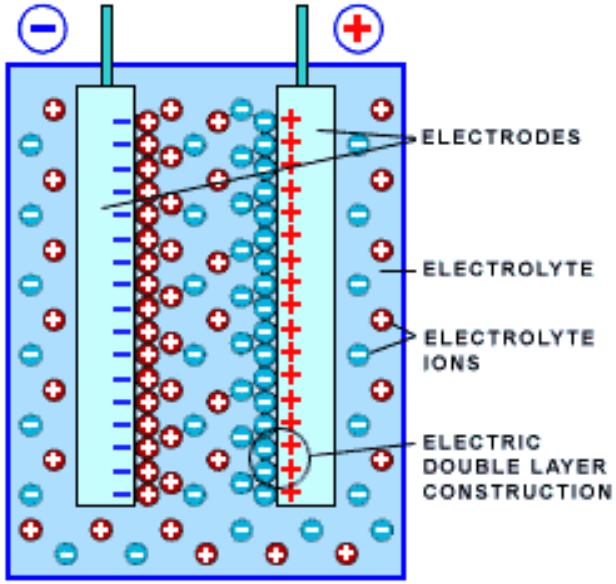




Supercapacitors

New technology applied to capacitors

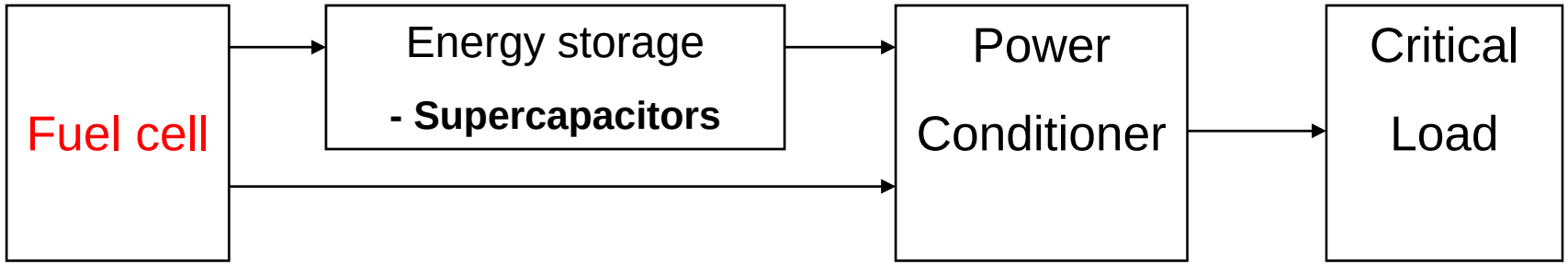
- High power density
- Long life and non-toxic



NESSCAP Supercapacitor

UPS with supercapacitors ESMA (1 MJoule, 1000 kg)

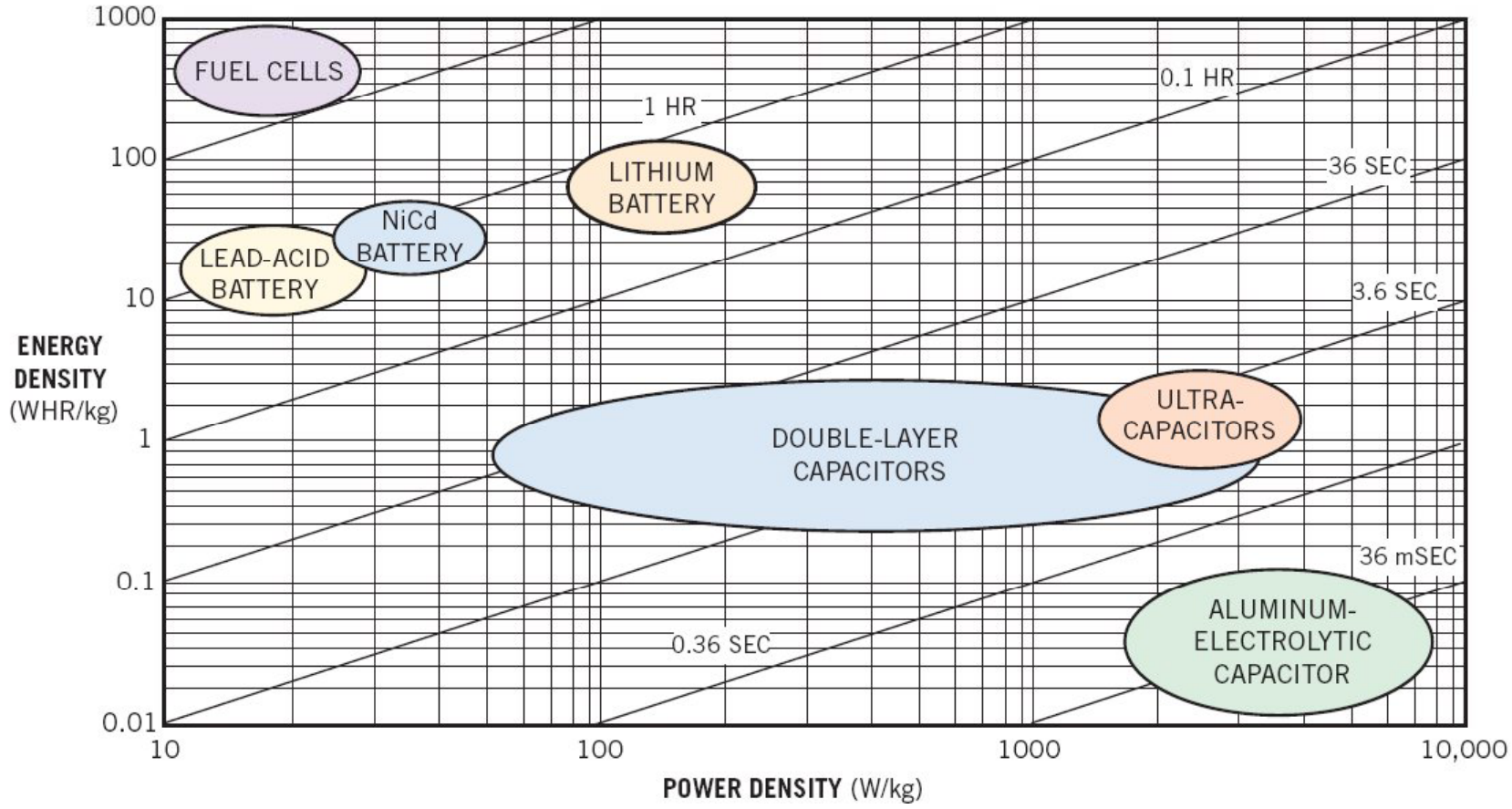
Supercapacitors boost the fuel cell performance



System requirements are:

- **Fast response to power quality disturbances and load following capabilities;**
- **High efficiency;**
- **Low environmental impact;**
- **Long lifetime.**

Supercapacitors boost the fuel cell performance



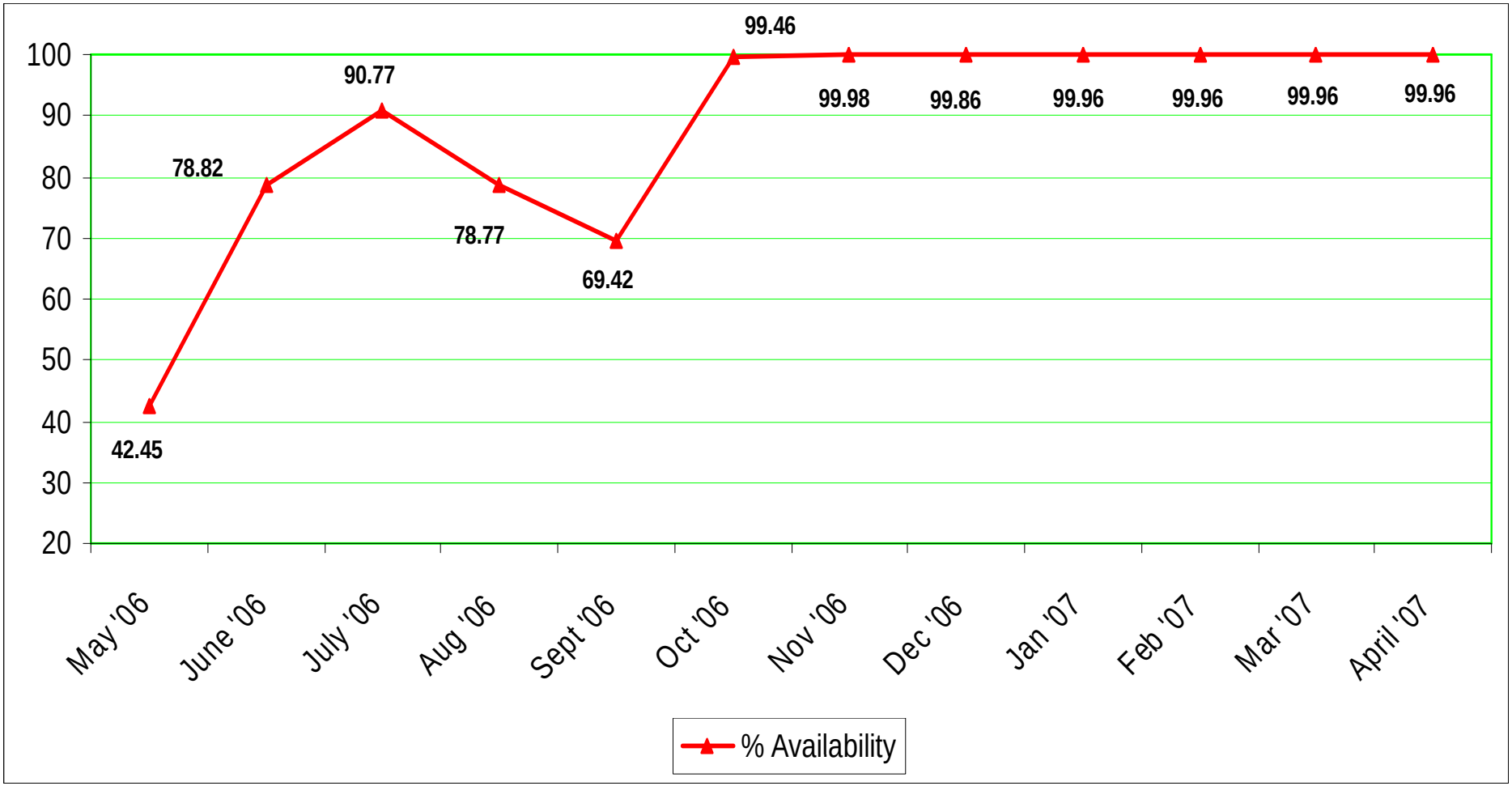
Graphing Energy Density against Power Density.

Why Fuel Cells?

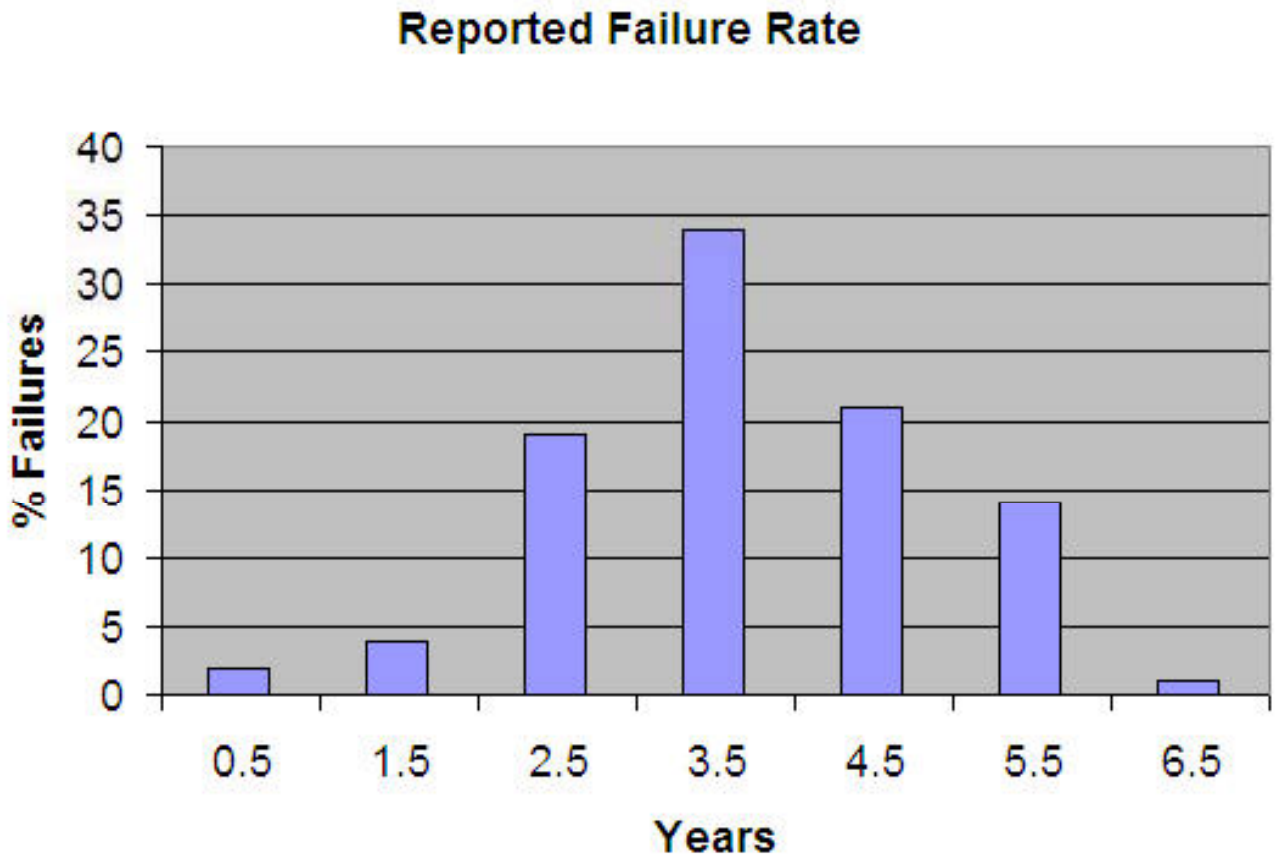
- **Availability**
  - **Greatly improves network reliability and disaster preparedness**
  - **Greater predictability and reliability then actionable alternatives**
  - **Extended run: provides power as long as there is fuel**
- **Suitability**
  - **Smaller footprint and packaging optimizes siting requirements**
  - **Lower weight attractive for rooftop sites**
  - **Environmental friendliness ideal for high population areas**
- **Simplicity**
  - **Sit and forget: self diagnostics and remote monitoring**
  - **Plug supports you from plan, design, implement and manage phase**
- **Affordability**
  - **Equal or greater performance/reliability at lowest cost of ownership**
- **Sustainability**
  - **Non polluting (low noise, and no direct emissions)**

GENCORE® VALUE ADDED

A major wireless carrier in Mexico switched to GenCore from batteries at a critical BTS site in October 2006. Availability increased to over 99.5%.



Batteries: *Reliability curve*



Study assessing indoor UPS batteries

BTECH®

AT&T Begins Massive Battery Replacement

JANUARY 15, 2008

After four equipment fires in two years, including a Christmas Day 2007 explosion in Wisconsin, AT&T Inc. (NYSE: T - message board) says it is no longer comfortable with the batteries powering thousands of its equipment cabinets in neighborhoods all over the U.S.