50.2 Hz

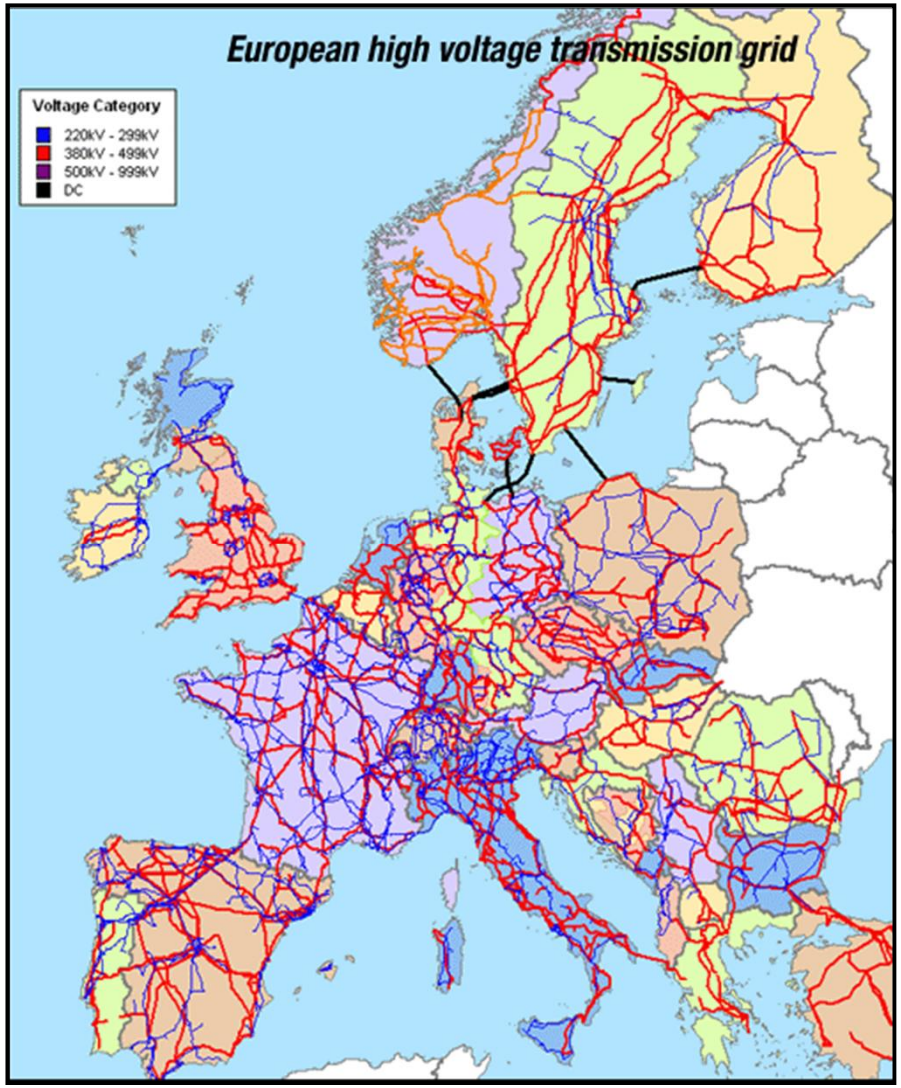
Local issues with global impact

Markus Gebhard, KA, Germany

elektro:camp(<<2012.10>>)

The European Power Grid

- System to supply electricity
- Built and expanded since 130 years
- Primary requirements
  - High availability
  - Protection of life and technical equipment
- Smartness built in
  - Selective deactivation of faulty parts
  - Redundant topology



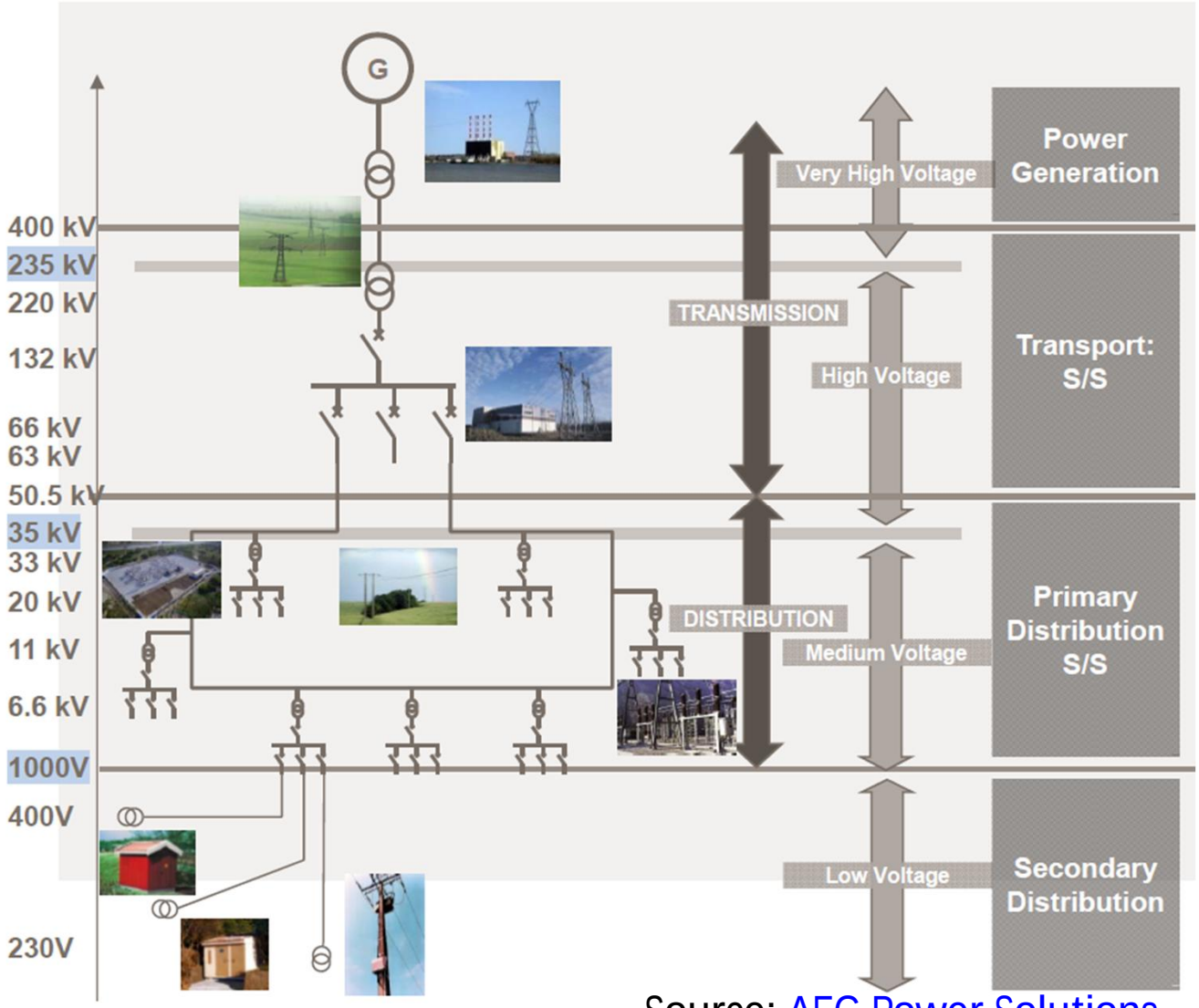
Source: geni.org: european national electricity grid

Some Numbers

- The European power grid is huge…
  - Serving 525.000.000 people
  - Transferring ~3.400 terawatt hours (TWh) per year (increasing)
  - 828 gigawatts (GW) installed generation capacity
  - 305.000 km high voltage network (transmission)
  - >5.000.000 km medium and low voltage network (distribution)
- …and follows a more centralized paradigm

*ENTSO-E data 2011

Grid Setup



Source: [AEG Power Solutions]

Achieving Grid Stability

- The grid transmits and does not store energy
  - What flows in needs to flow out and vice versa
  - Supply and consumption need to be balanced
- The European transmission grid is connected
  - Balancing grid partitions on failure or instability within seconds
  - High voltage smart grid

Principle of Grid Management

- The European Power Grid is based on
  - Alternating Current (AC)
  - Wide area synchronous grid at 50,0 Hertz (Hz)
- Correction active at a difference of +/-20mHz
  - Δ < 200mHz primary power adjustment up to 3 GW for 30 seconds
  - Δ < 800mHz can be handled
  - Δ > 800mHz causes black out and net restart

Grid Management Issues

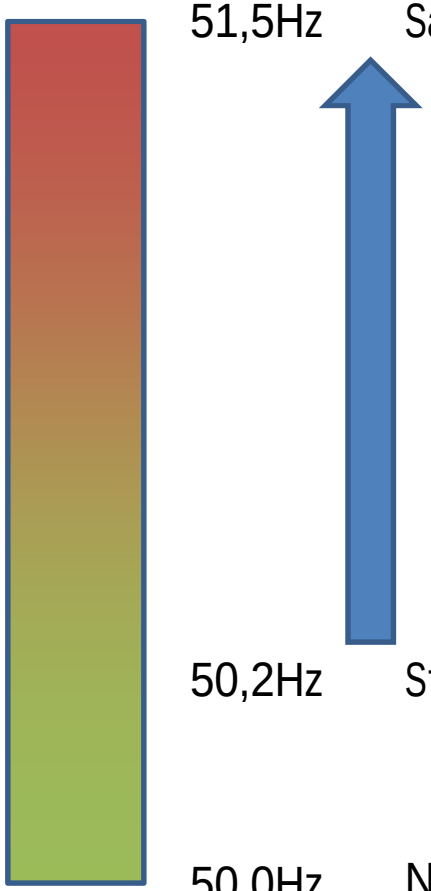
- Principle based on large scale power plant adjustment capabilities in the wide area grid
  - Inertia of generator flywheels
  - Adjustment on transmission level – classic generation and transport layer (high voltage)
- Generation/transmission paradigm changes
  - Wind turbines and PV generators supply on „former“ distribution level - not part of the primary adjustment level
  - Neither PV nor wind generators have flywheels
- Consequence: Management required also on distribution level

Easy solution

- If 50,2Hz are reached, switch off local supply (rule until 2011)
- This means for example:
  - Karlsruhe (Germany) has a total of
    - 16,5 MW installed photovoltaic supply
    - 1,6 MW installed wind electricity supply
  - Taking these off grid immediately may cause a severe drop on distribution level leading to a cascade... - Karlsruhe gets dark (not nice)

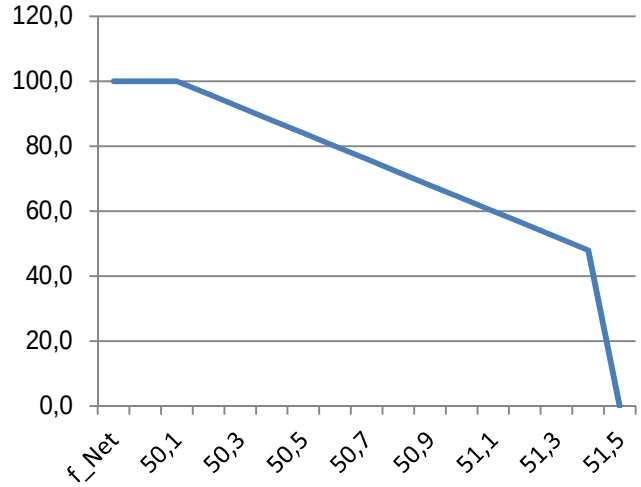
More Sophisticated Solution

- Graded handling in a wider frequency range



51,5Hz Safety switch off

Reduction of effective power output
with gradient of 40%/Hz
of the effective power produced at time of passing 50,2Hz

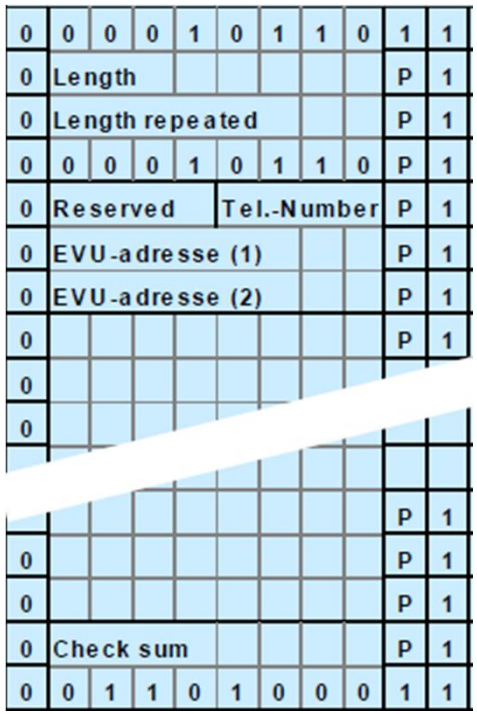


50,2Hz Start of adjustment range

50,0Hz Normal operation

Alternative Solution

- Individual supplier load management via ripple control
  - Frequency ripple control (modulated on power line)
  - LW-radio control (using long wave transmission)
- Direct influence on individual supply parameters
  - Effective power supply switching in a variable number of steps
  - For example: 100%, 60%, 30%, 0%, Off

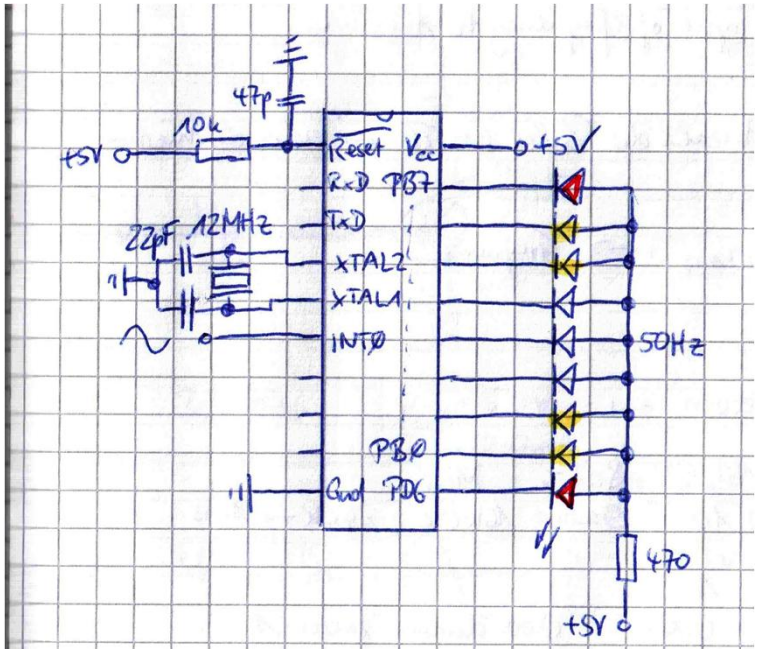


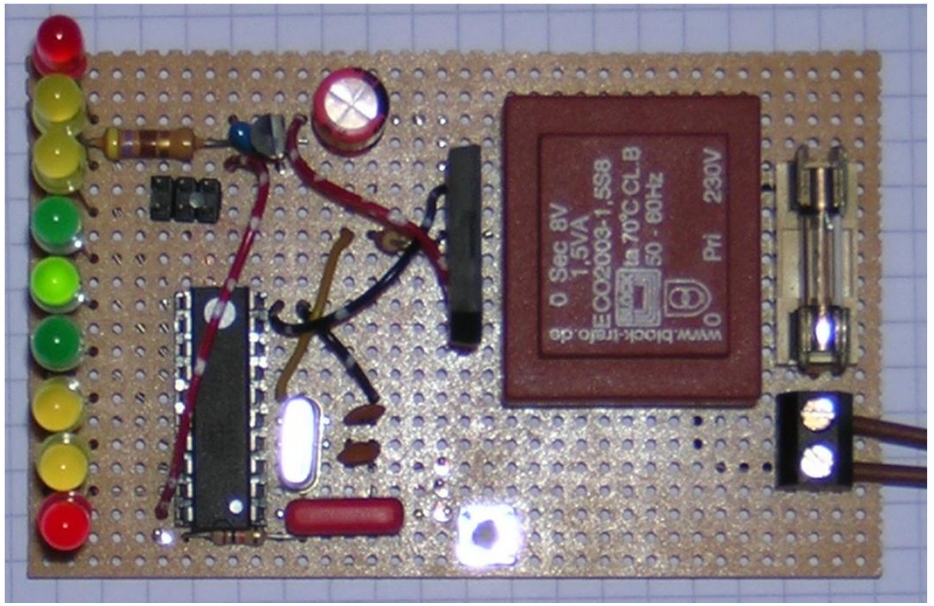
Source. www.efr.de

Hardware Hacks

- Grid frequency measurement
- Ripple control decoding

Net frequency measurement

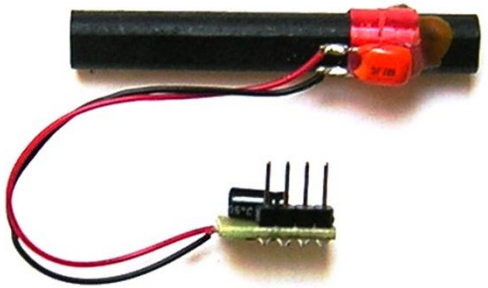




Code: https://github.com/gebhardm/energyhacks/tree/master/Netfrequency

Ripple control decoding

- Ripple control telegrams are transmitted
  - Either via the power line
  - Or via long wave transmission operated by the „European Ripple Control Inc.“ (Europäische Funk-Rundsteuerung GmbH (EFR))
    - Mainflingen (Germany) - 129,1 kHz (DCF49)
    - Burg (Germany) - 139 kHz (DCF39)
    - Lakihegy (Hungary) - 135,6 kHz (HGA22)
- As receivers are rather expensive, a cheap DCF77 receiver may be used with an altered LC resonator



See: http://de.wikipedia.org/wiki/Funkrundsteuertechnik

Resources

- www.geni.org – Global Energy Network Institute
- www.bundesnetzagentur.de – German Federal Network Agency
- www.netzfrequenzmessung.de – online net frequency measurement
- www.entsoe.eu – European network of transmission system operators for electricity
- www.efr.de – European Radio Ripple Control Ltd.: system operator for long wave energy management service
- www.vde.com – study on 50,2 Hz problem