LHC machine EMC Workshop

25th Nov. 2004

POWER QUALITY, LHC EARTHING AND CABLE INSTALLATION

1. **Definition** of Power Quality and Network Disturbances
2. **Statistics** 2003
3. **Harmonics**
4. LHC **Engineering Specification**
5. LHC **earthing system**
6. LHC **cable installations**
7. **Conclusions**

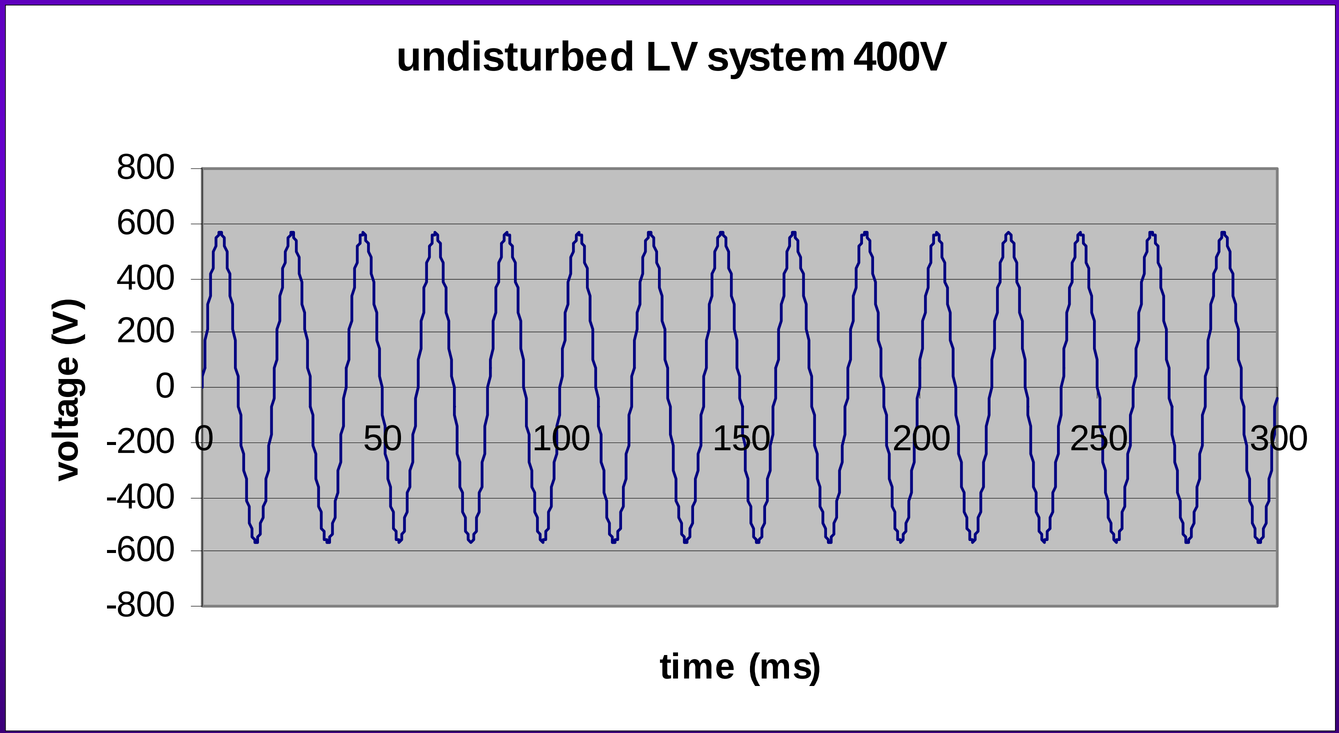
K. KAHLE, TS-EL

Standards and Norms

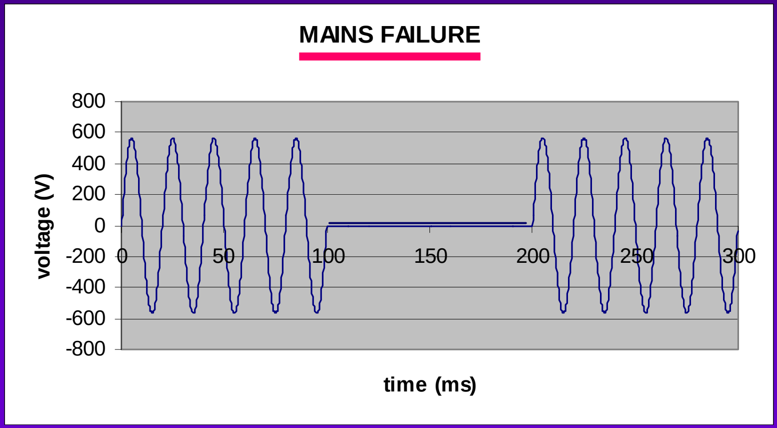
EN50160	Voltage characteristics of electricity supplied by public distribution systems
IEC61000-2-2	Compatibility levels for low frequency conducted disturbances
IEC61000-2-4	Compatibility levels in industrial plants for low frequency conducted disturbances
IEC61000-2-12	Compatibility levels for low frequency conducted disturbances in MV systems
IEC61000-3-4	Limitations of emissions of harmonic currents for equipment > 16A
IEC61000-3-6	Assessment of emission limits for distorting loads in MV and HV power systems

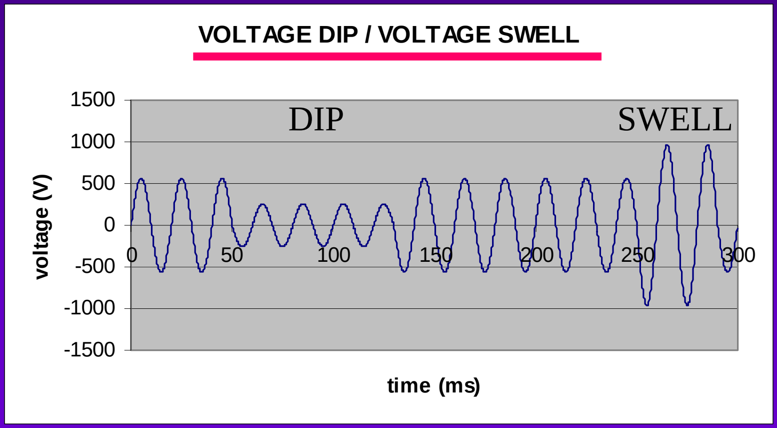
Power Quality

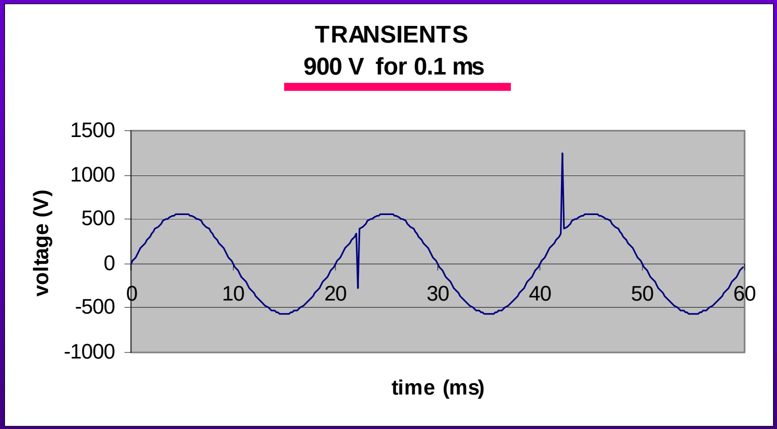
= Quality of electrical energy supplied

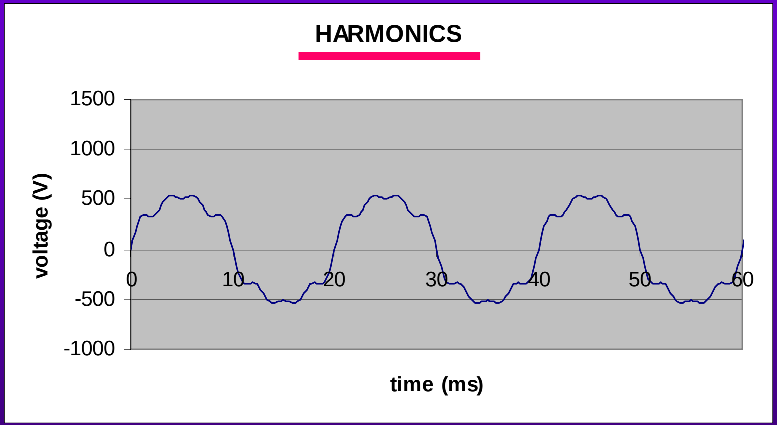


Types of network disturbances









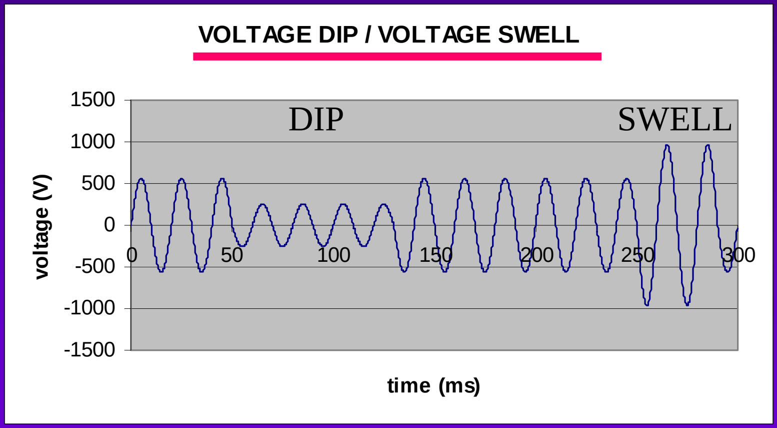
Definition | Statistics | Eng.Spec. | Earthing | Cabling | Conclusions

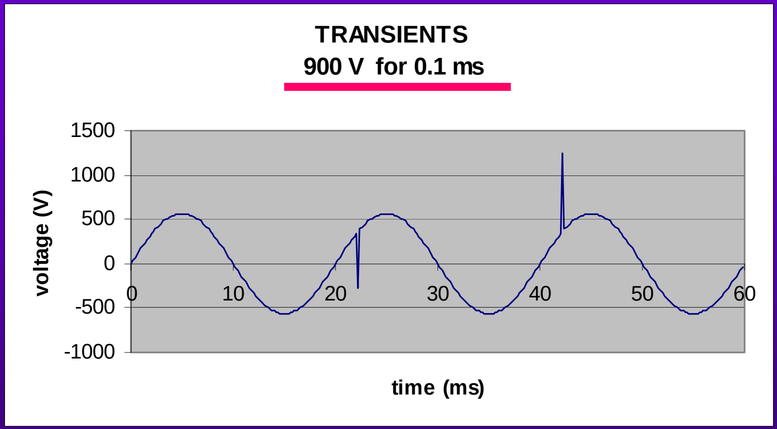
Types of network disturbances

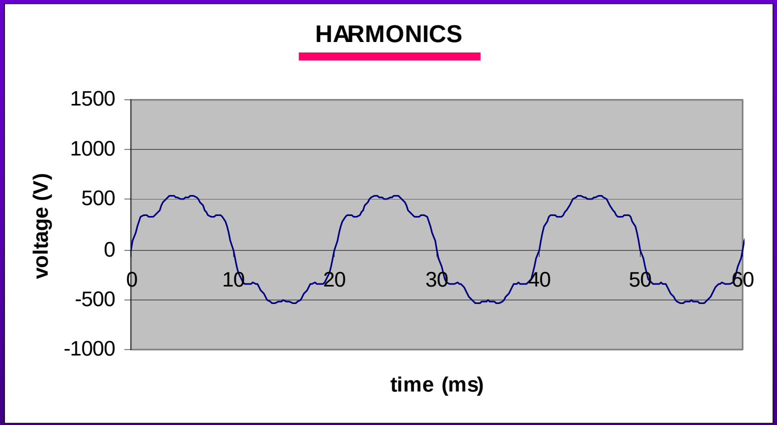
MAINS FAILURES

Causes:
- thunder-storms
-short-circuit inside CERN
- Emergency Stop operation

Consequences:
- accelerator stop







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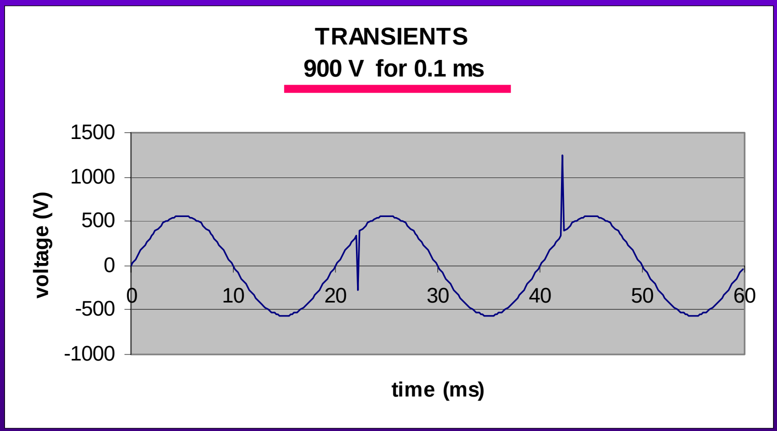
VOLTAGE DIP / SWELL

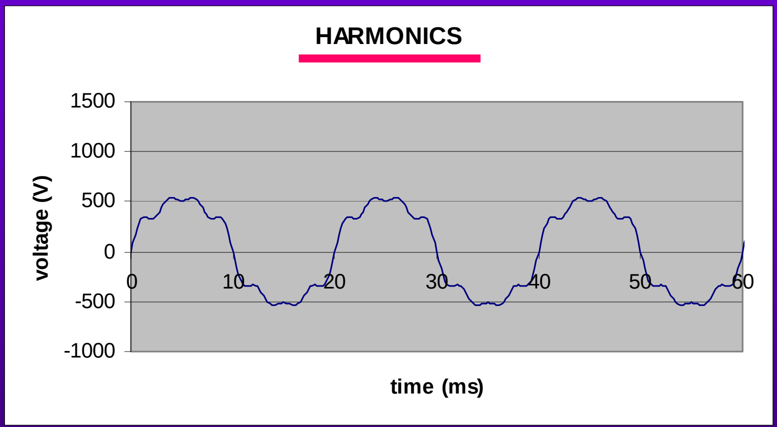
Causes:

- sudden change of load, inrush
- short-circuits inside & outside CERN
- thunder-storms

Consequences:

- sometimes accelerator stop





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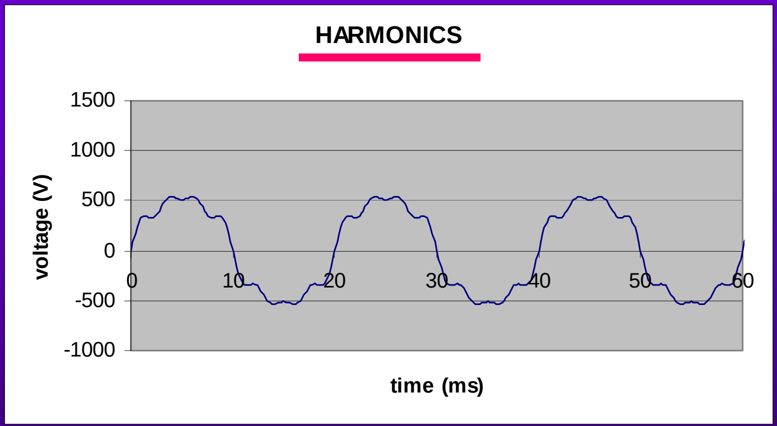
TRANSIENTS

Causes:
- switching compensators ON
- power converters (thyristors)
- thunder-storms

Consequences:
- failure of electronics



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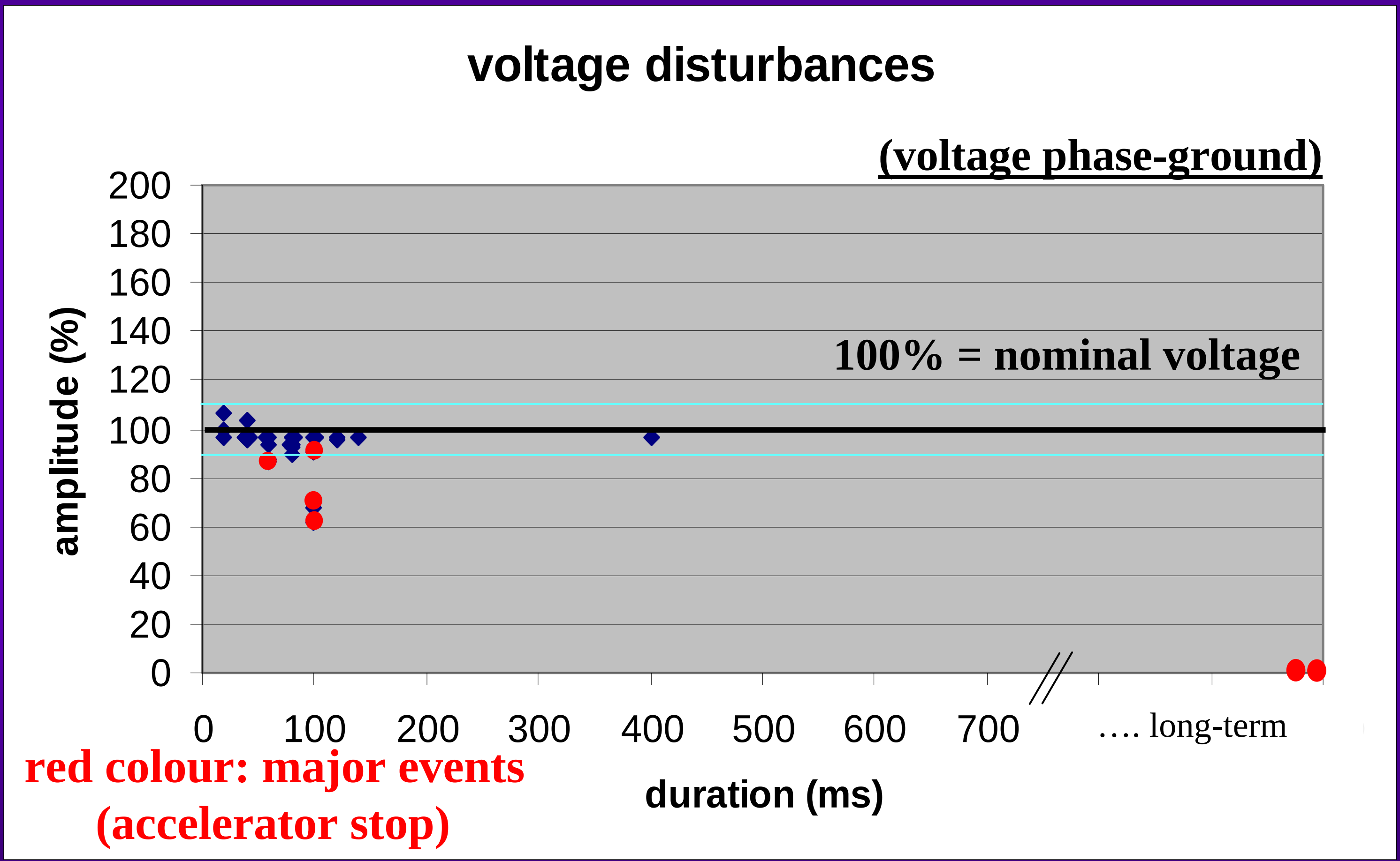
HARMONICS

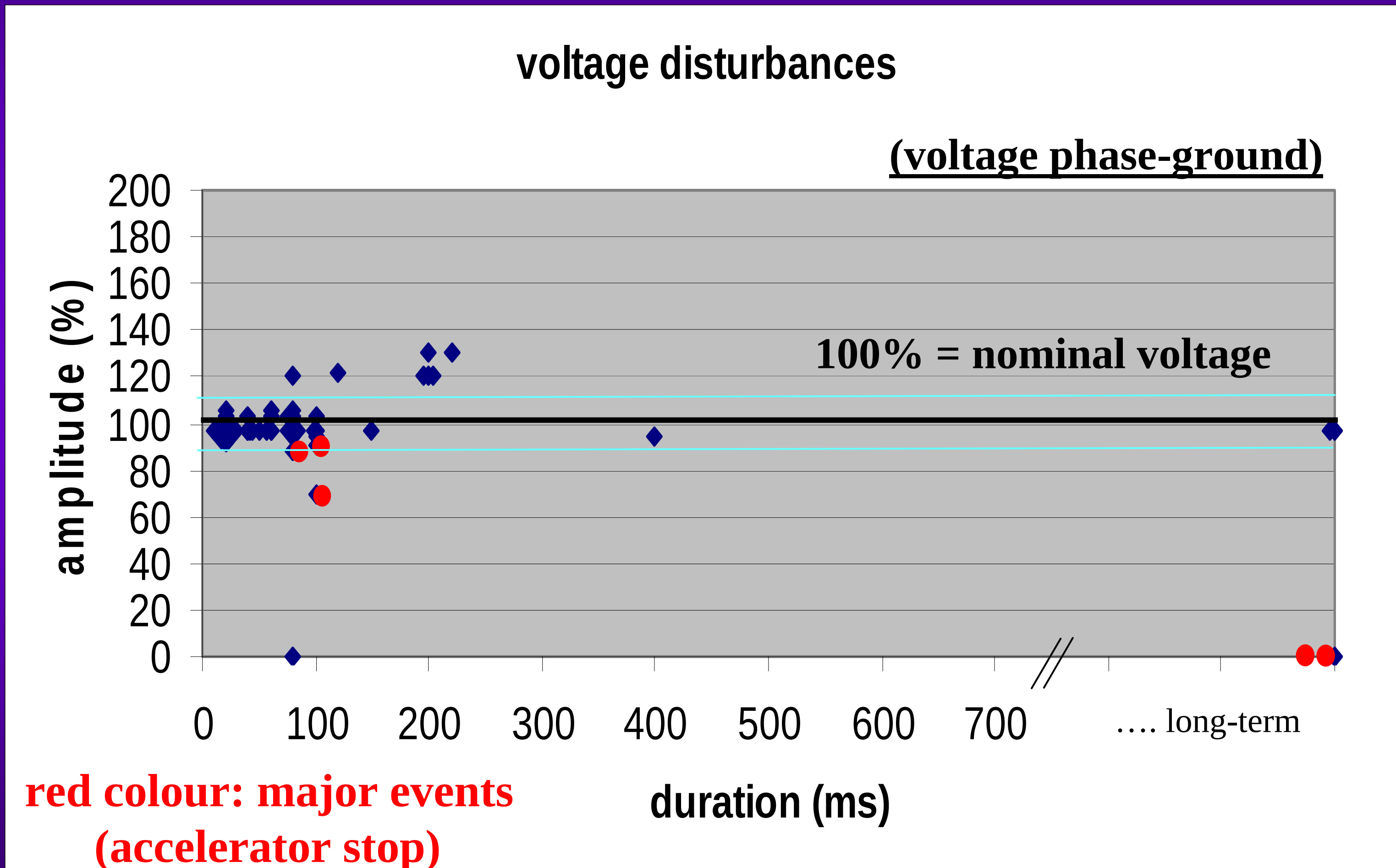
Causes:
- non-linear loads
  (office PC's, power converters etc.)

Consequences:
- malfunctioning of electronics

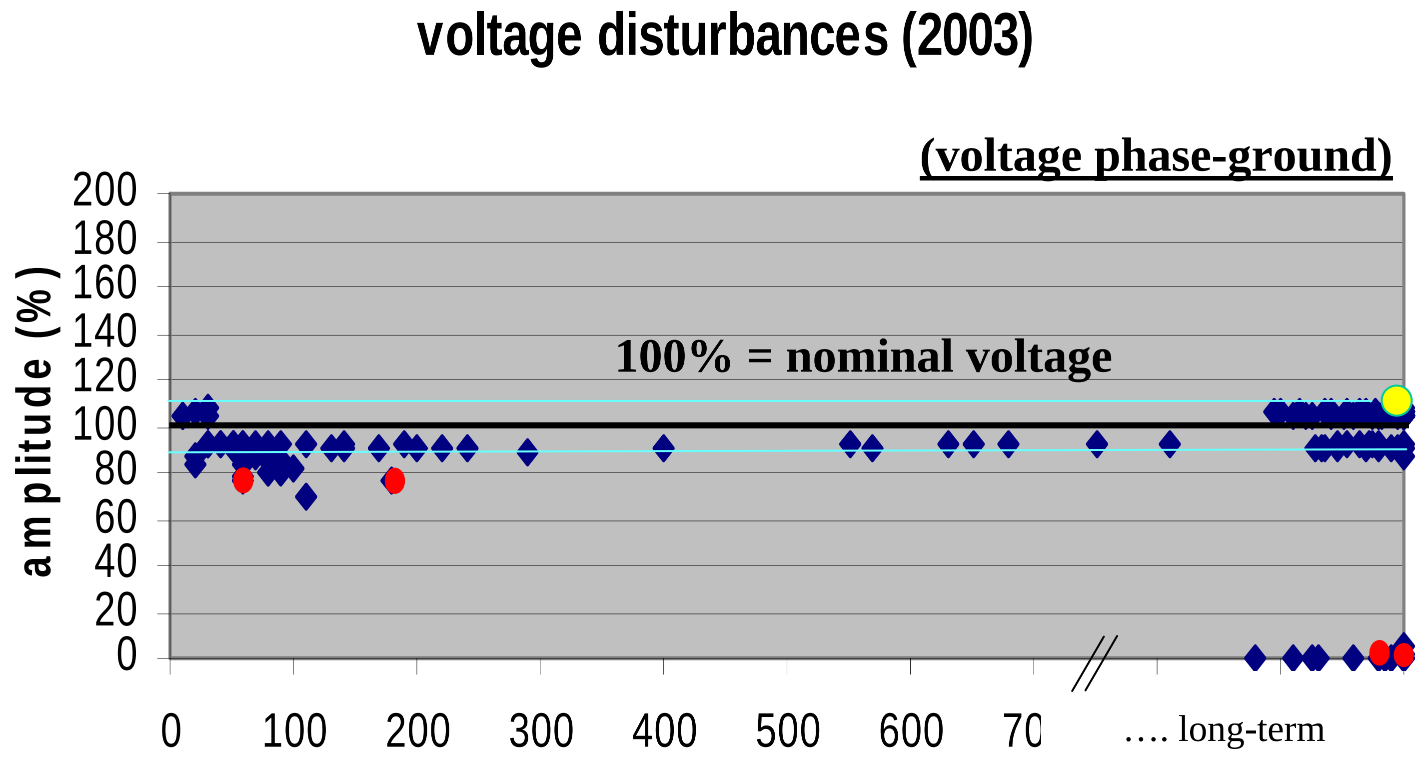
Statistics 2003: 400kV network



Statistics 2003: 18kV network



Statistics 2003: 400V network



red colour: major events (accelerator stop)

yellow: Blackout Italy (28.9.2003)

Worst-case Undervoltages 0.4kV (2003)

Dip	Duration	Location	Cause
- 71 %	180 ms	Buildg. 2660, PA6	short circuit 18 kV
- 34 %	110 ms	Station ERD1/8R	thunder-storm
- 32 %	130 ms	Buildg. 2260, PA2	thunder-storm
- 30 %	110 ms	Booster SVC	thunder-storm
- 28 %	70 ms	Station ERD1/8R	thunder-storm

(voltages phase-ground)

Worst-case Overvoltages 0.4kV (2003)

Swell	Duration	Location	Cause
+ 25 %	30 ms	ESD1/BK6	unknown
+ 20 %	30 ms	ESD1/BK6	unknown
+ 18 %	50 ms	EYS01/PA6	unknown
+ 16 %	50 ms	EYS01/PA6	unknown
+ 13 %	10 ms	EAD345/PA2	unknown

(voltages phase-ground)

Statistics: network disturbances

The MAJORITY of network disturbances is caused WITHIN CERN.

The MAJORITY of network disturbances has no consequences.

Main cause of Major Events: thunder-storms

Harmonics

Harmonic distortion:
- up to 40th
- even harmonics are low (symmetry)

$$THD = \sqrt{\sum_{n=2}^{40} \left(\frac{I_n}{I_1}\right)^2}$$

CERN – harmonic levels:
THD [IEC 61000-2-4 (class 1)] max. 5 %
- See engineering Specification

Exception: large quantities of similar power converters connected to one transformer (e.g. LHC powering, ADT converters, CERN Computer Center build. 513)
- Study required

Harmonics

Harmonic emission (non-linear loads):

- 6-pulse thyr. power converters: 5, 7, 11, 13th
- 12-pulse thyr. power converters: 11, 13, 23, 25th
- single-phase PC's: 3, 5, 7th

(If 3rd harmonics: Neutral current can exceed phase current!)

Remedies:

- Limit harmonic emission of load (IEC61000-3-2 and 3-4)
- 12pulse instead of 6pulse
- reduce network impedance (cables, special transformer)
- harmonic filters (Static Var Compensator 18kV)
- transformers: earthed screen between HV/LV winding
- *separate machine and general services !*

LHC Engineering Specification

Nominal voltage	400/230 V
Maximum operating variations	+/-10 %
Nominal frequency	50 Hz
Maximum variations	+/-0.5 Hz
Total Harmonic Distortion, THD	5 %
Voltage unbalance	2 %

LHC Engineering Specification

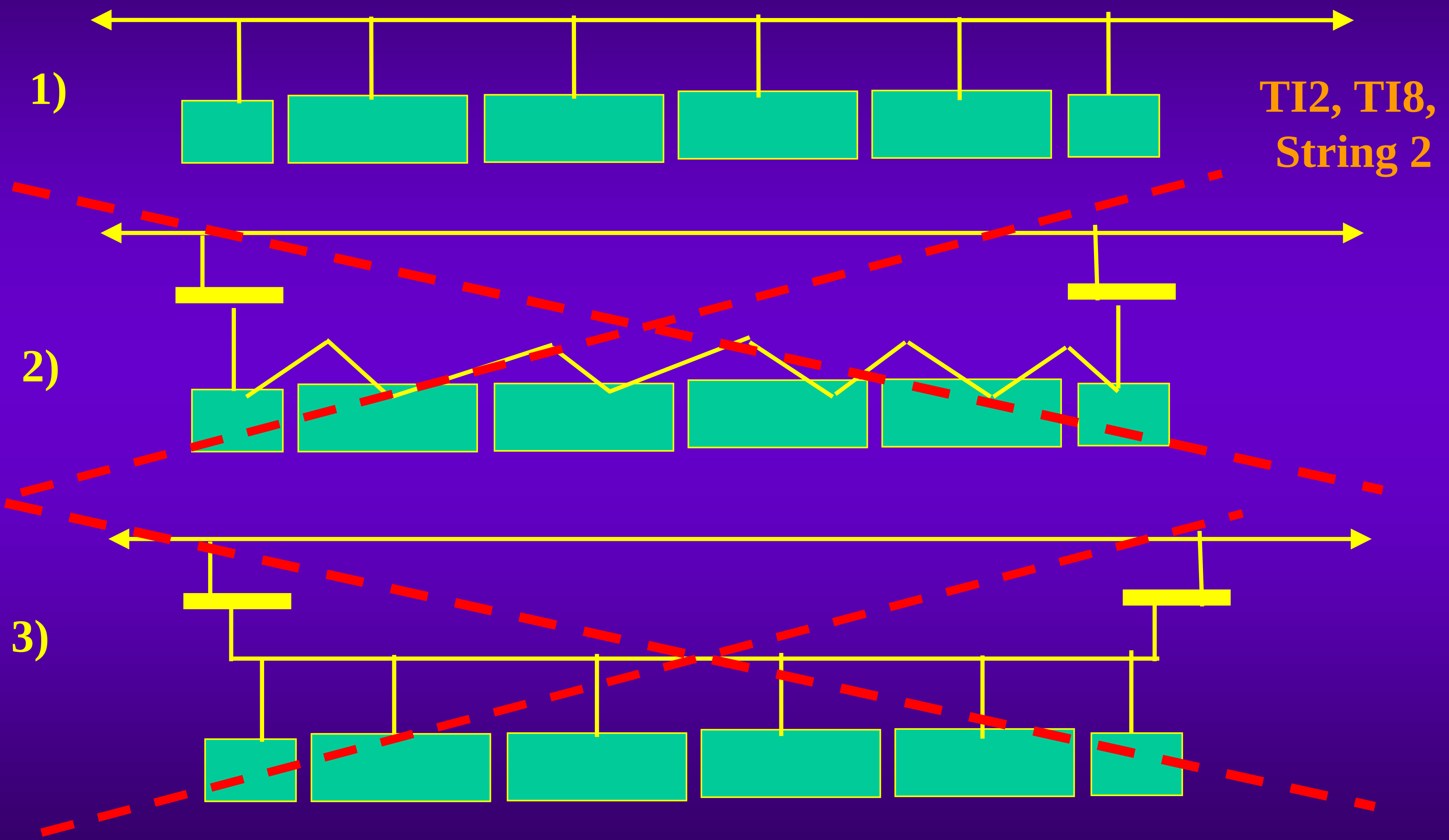
Transient voltage disturbances:

Peak mains surges	**1200 V for 0.2 ms**
Mains over voltage, typical value	**50% of Un for 10 ms**
Voltage drops	**50 % of Un, typically 100 ms**

LHC earthing system

- at CERN: TN-S low voltage system (earth and Neutral separate)
- One single earthing system (not several different earthing systems!!!)
- systematic ‘meshing’ of the earthing system
- EVERYTHING connected to the earthing system
- 120 mm2 along the LHC tunnel
- 120 mm2 around each Alveole
- 120 mm2 connected to the underground building structure
- 120 mm2 connected to the surface building structure (via shafts)
- 120/240 mm2 connected to the transformer starpoints

LHC earthing system (tunnel)



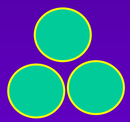
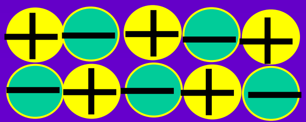
Definition | Statistics | Eng. Spec. | **Earthing** | Cabling | Conclusions

LHC cable installations

Cable ladders around LHC:

- Earthing cable 120mm2 all around the machine
- connected to earthing system every 25m
- sections: electrically interconnected
- parallel cable ladders: electrically interconnected
- good for equipotentiality

LHC cable installations

- all TS-EL cables (power + control): screen earthed on both ends
- AC three-phase cables installed in tri-fold arrangement 
- max. 2 layers of power cables
- polarity of DC cables 

- user's cables: screen earthed acc. user's convention
- separation: CONTROL – DC – AC (different cable ladders)
- UA straight sections: separation CONTROL – BDI (coax. meas.)
- safety cables (Alarm 3, AUG, safety lights): 'goulotte de sécurité'
- RF and Kicker cables: separate cable ladders

Cable screens

General rule: earthing of cable screens on both sides !

- Power cables HV, LV
- HF and LF coax. cables
- measurement cables
- signal cables

Exception, if 5 conditions are fulfilled simultaneously:

-See Alain CHAROY

- e.g. Cryo temperature measurement CERNOX
- e.g. Huba Piezo Gauge

Conclusions 1/3

Transient network disturbances:

* MAJORITY of network disturbances is caused WITHIN CERN

* MAJORITY has no consequences

* Main cause of Major Events: thunder-storms

* To assure the functioning of equipment through disturbances, definition of tolerance levels for user's equipment:

LHC Engineering Spec. EDMS113154 (28.07.2000)

"Main Parameters of the LHC 400/230V Distribution System"

Conclusions 2/3

Earthing System:

* Equipotentiality
* as many interconnections as possible (mesh)
* as many loops as possible (mesh)
* all buildings interconnected
* one single earthing system for EVERYTHING
* connected to the building structure
* connected to all metallic parts (rails, racks, platforms)
* connected to all transformer starpoints
* Earth connections of equipment as short as possible

Conclusions 3/3

Cabling:

* Separation of CONTROL – AC – DC cables
* Screen earthed on both ends
* AC 3phase cables in tri-fold

Questions ?

Thank you.