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ELECTRICAL SERVICE CONTINUITY IN HOSPITALS EXPOSED TO SEISMIC HAZARD

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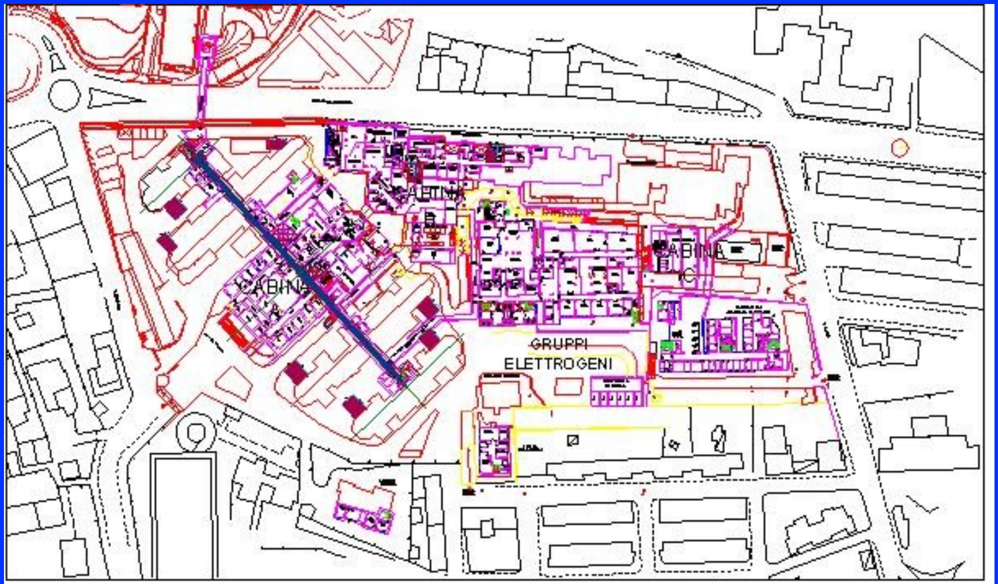
Introduction

The earthquake causes serious problems to the functional <u>reliability and continuity</u> of supply of electrical power systems particularly in <u>exposed and sensitive structures</u> as hospitals and strategic buildings.

Introduction

The paper discusses the need of studying the requirements for the design and installation of electrical power systems in buildings subject to seismic hazard

The hospitals have the main goal of the service continuity and of spending energy to save lifes



Cosenza Hospital (Italy)

Hospitals like Data Centers need standard equivalent to TIA 942

Introduction

Power systems considered to be "subject to seismic hazard"

Buildings located in seismic-hazard areas:

- **High occupancy level**
  (cinemas, commercial, schools, etc)
- **Relevant importance**
  (railway stations, airports, etc.)
- **Strategic importance - Service continuity**
  (hospitals, fire brigade buildings, telecommunication systems, etc.)

Performances VS classes of operation

Electric operational performances of buildings versus seismic phenomena	Three classes of operation
1) to guarantee the safety of personnel during the earthquake and to mitigate the damages	1) First class of operation mitigates possible damages caused by the system components.
2) to re-establish electric operation soon after the earthquake	2) Second class of operation guarantees the mechanical resistance of the system components.
3) to maintain electric operation during and after the earthquake.	3) Third class of operation guarantees the electrical operation of the system components.

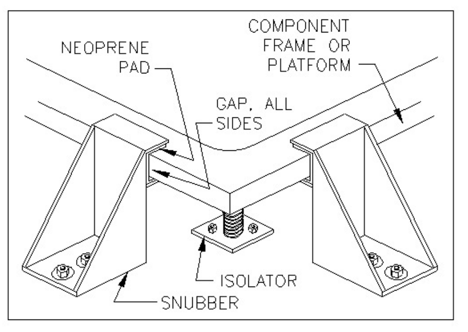
Introduction

The seismic design of a power system needs tested components to tolerate and/or mechanically resist the expected forces

DESIGN AND INSTALLATION FOR PREVENTING SEISMIC STRESSES

In hospitals it is necessary to ensure that electrical service will be available following an earthquake

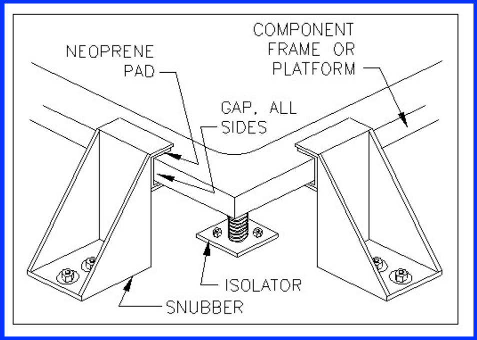
Distributed systems and equipment **require special supports and anchorages (snubbers, bolts, brackets or assembling on vibration isolators)**



DESIGN AND INSTALLATION FOR PREVENTING SEISMIC STRESSES

Batteries, inverter-rectifier units, containers for lighting fixtures, suspended false ceilings, and cable ducts

must be considered for **seismic evaluation and special anchoring techniques** **(shock spacers, fall arresters and safety fastens, lateral restraints) .**



DESIGN AND INSTALLATION FOR PREVENTING SEISMIC STRESSES

Important goal:

to coordinate the non structural design criteria with a layout of the system architecture that *avoids or intrinsically limits* the seismic exposition

darwinian approach

that has to be coordinated with the dislocation of hospital functional areas

G. Parise, M. De Angelis, A. Reggio "A Darwinian Evolution Of Electrical Power Systems Design For Preventing Seismic Risks In Sensitive Buildings", 2011 IEEE/ I&CPS Technical Conf., Newport Beach, California, USA, May 1-5

A DARWINIAN APPROACH IN THE DESIGN OF THE ELECTRICAL STRUCTURE

Darwinian design criteria **are:**

1) **Minimize the mass (weight) of each component of the system (*microsystem approach*);**

2) **Minimize the seismic acceleration on the component by locating it as close to ground level as possible (reduction of the exposure to the seismic force F_c characterized by the installation height ratio z/h).**

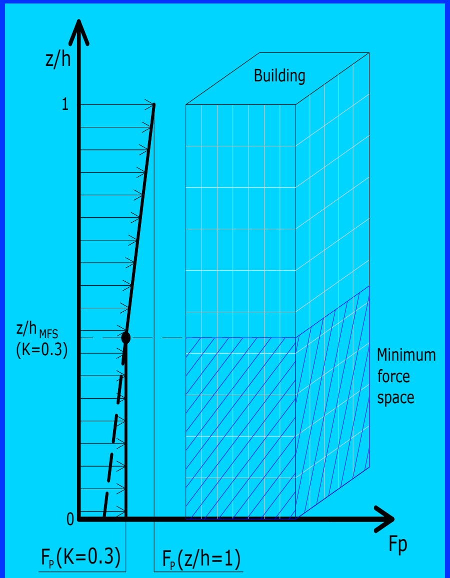
A DARWINIAN APPROACH IN THE DESIGN OF THE ELECTRICAL STRUCTURE

The behavior of the building structure is important to **recognize the distribution of seismic forces inside the building volume** and specially to identify the volume

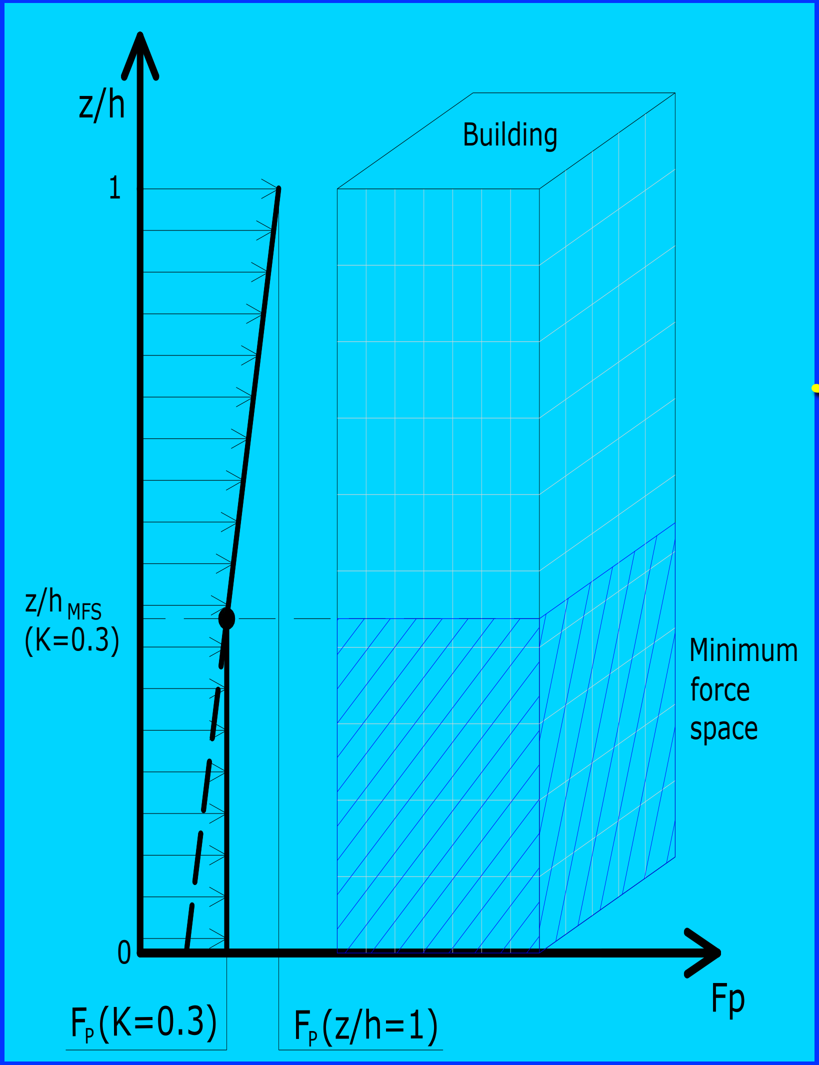
Minimum Force Space

MFS

G.Parise, L. Martirano, G.Fox "Electrical Power Systems Availability In Buildings Exposed To Seismic Hazard Part I - Electrical Criteria Part II - Mechanical Criteria" IEEE Transactions on IA , Volume: 47, Jan-Feb 2011, pages: 292-300



A DARWINIAN APPROACH IN THE DESIGN OF THE ELECTRICAL STRUCTURE



The MFS defines the building volume inside where ***the seismic design force applicable to equipment is lower than the recommendable minimum value*** that has to be assumed as reference for sizing and installing adequately the components.

SEISMIC FORCES EVALUATION

An *equivalent static lateral force method* has been developed for the seismic analysis of nonstructural components in a simplified approach (*ordinary cases*).

***Seismic action effects* are determined by applying at the component's center a horizontal force F_c whose general format is given by**

$$F_c = \frac{W_c\, a_g\, A}{q_c}$$

SEISMIC FORCES EVALUATION

$$F_c = \frac{W_c \, a_g \, A}{q_c}$$

where

W_c is the **operating weight** of the component

a_g is the **peak ground acceleration**, expressed in p.u. gravity acceleration; typically $0.0 \le a_g \le 1.0$

q_c is the **behavior factor**, which accounts for the ductility capacity of the component to reduce the lateral force; typically $1.0 \le q_c \le 4.0$

A is the **dynamic amplification factor** of the peak ground acceleration to the component acceleration

SEISMIC FORCES EVALUATION: DIFFERENT INTERNATIONAL APPROACHES

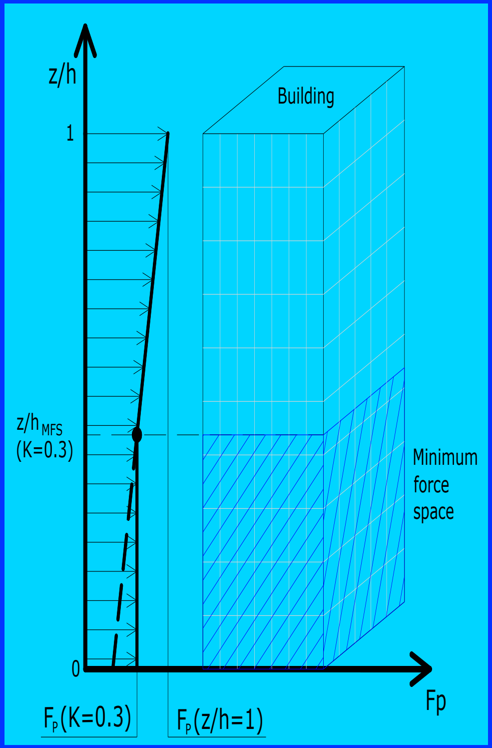
Current building codes in high seismicity countries, like in United States, in New Zealand or in Europe *(FEMA 450/2003, NZS 4219:2009 and Eurocode EC8)* have developed seismic design requirements: *the three building codes* provide *different formulations* of the seismic force F_c depending on the definition of *the dynamic amplification factor A*

SEISMIC FORCES EVALUATION

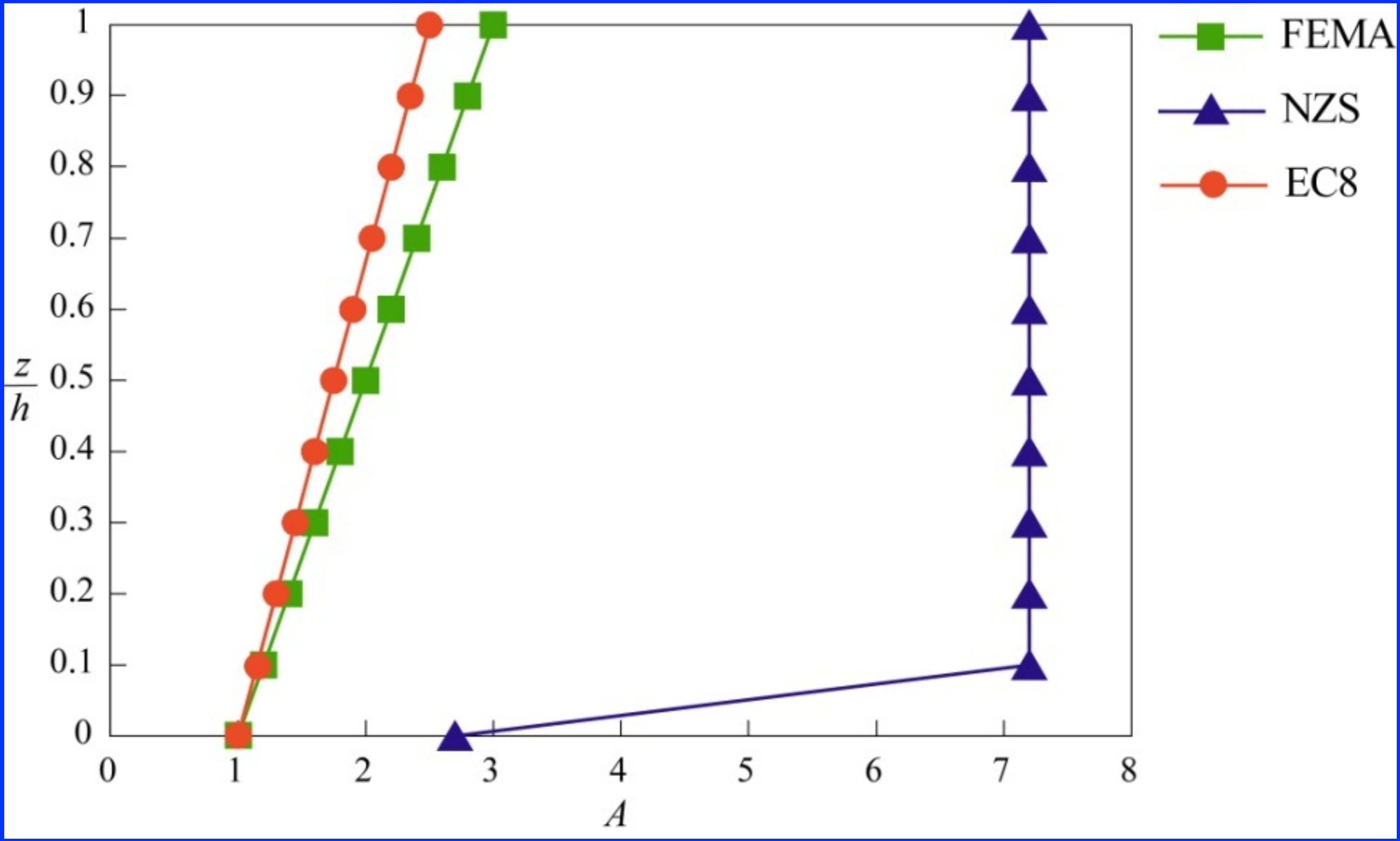
the **dynamic amplification factor *A*** can vary:

- on the ratio *z/h* : *z* is the height of the nonstructural component and *h* the building height, both measured above the foundation level

z/h

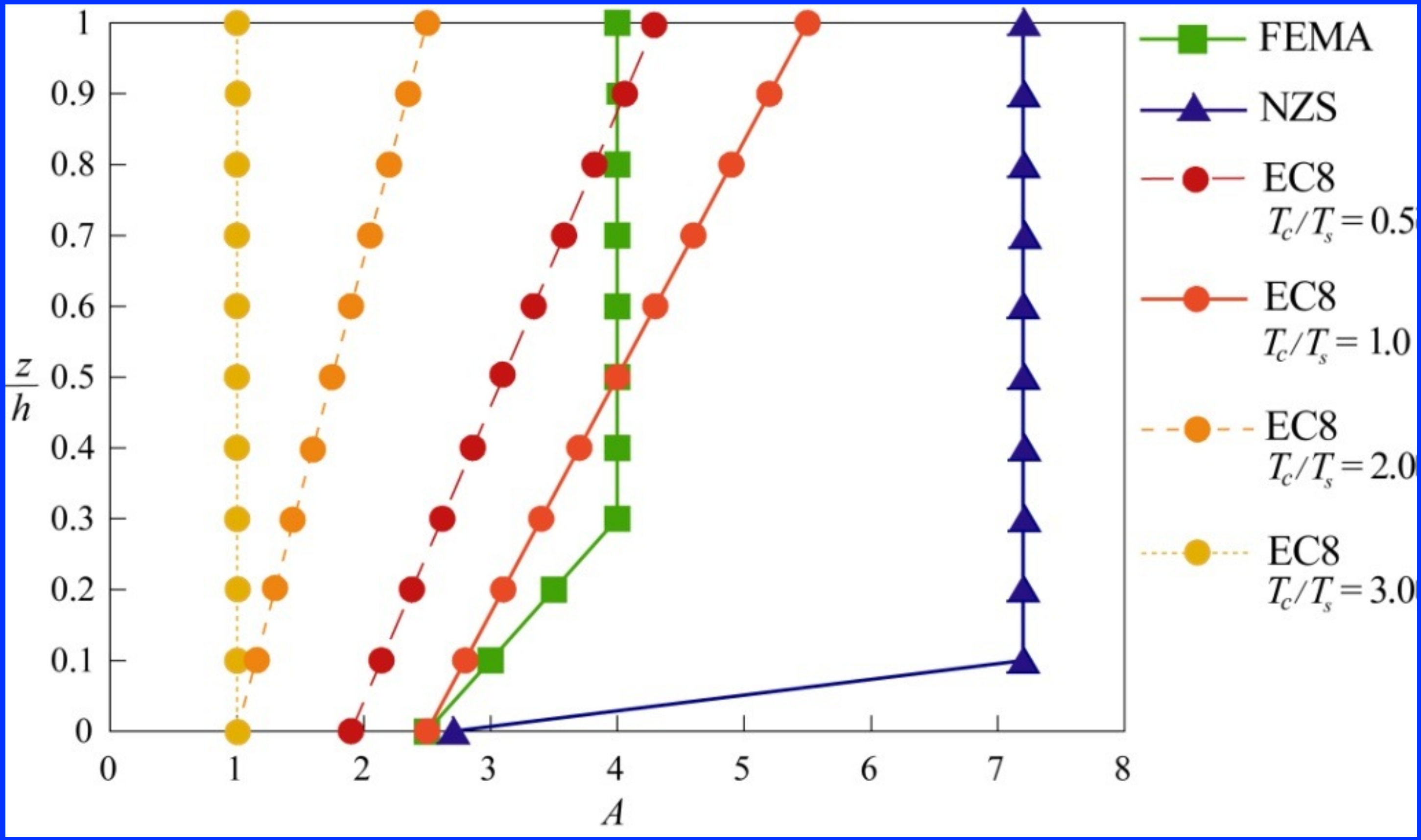


-on the *fundamental natural vibration periods* of the component (T_c) and its supporting structure (T_s): flexible components (**EC 8**)



Dynamic amplification factor A for a *rigid nonstructural component:* comparisons between FEMA 450/2003, NZS 4219:2009 and Eurocode 8 (EC8). It is assumed $q = 1.00$, $a_g = 0.5$

G. Parise, M. De Angelis, A. Reggio "A Darwinian Evolution Of Electrical Power Systems Design For Preventing Seismic Risks In Sensitive Buildings", 2011 IEEE/ I&CPS Technical Conf., Newport Beach, California, USA, May 1-5



Dynamic amplification factor *A* for a flexible nonstructural component: comparisons between FEMA 450/2003, NZS 4219:2009 and Eurocode 8 (EC8). It is assumed $q = 1.00$, $a_g = 0.5$.

G. Parise, M. De Angelis, A. Reggio "A Darwinian Evolution Of Electrical Power Systems Design For Preventing Seismic Risks In Sensitive Buildings", 2011 IEEE/ I&CPS Technical Conf., Newport Beach, California, USA, May 1-5

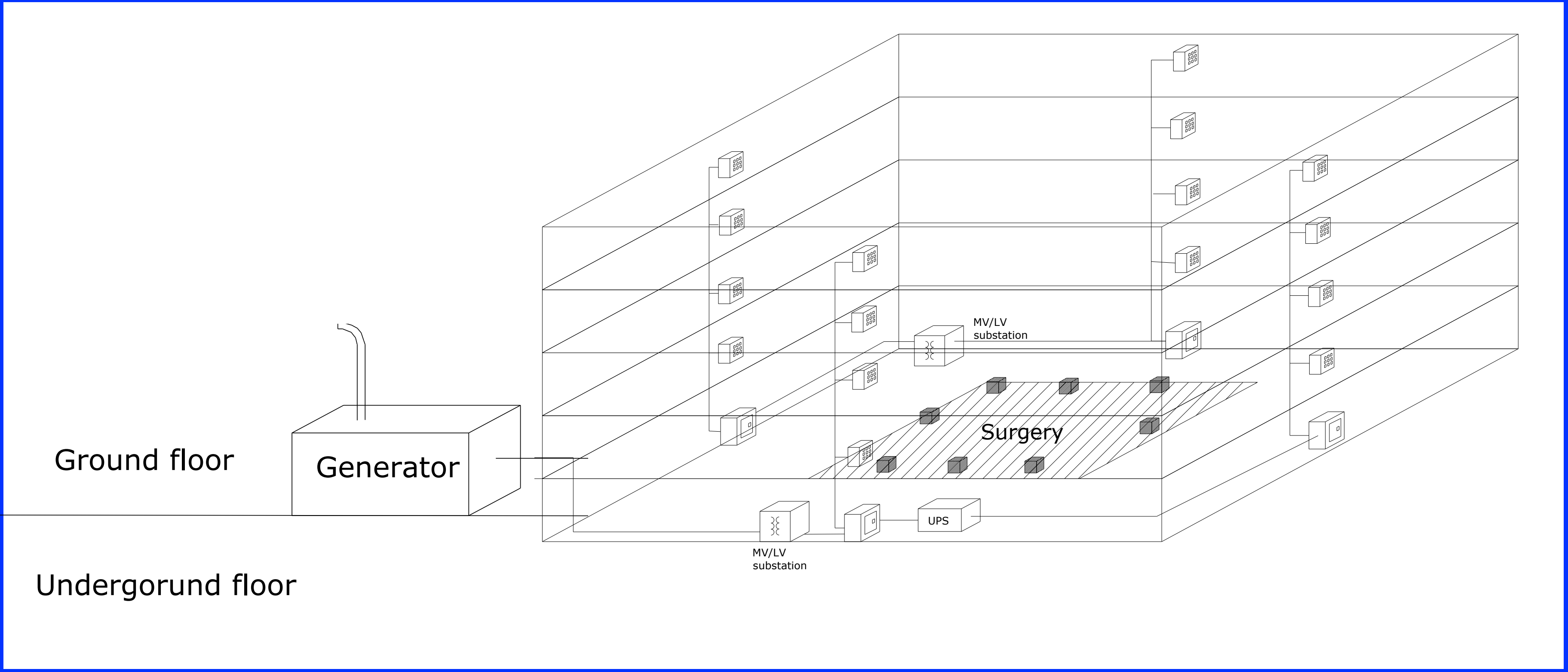
DESIGN AND INSTALLATION: MECHANICAL CRITERIA

1) Minimize weight (W_c) of each component of the system

microsystem approach

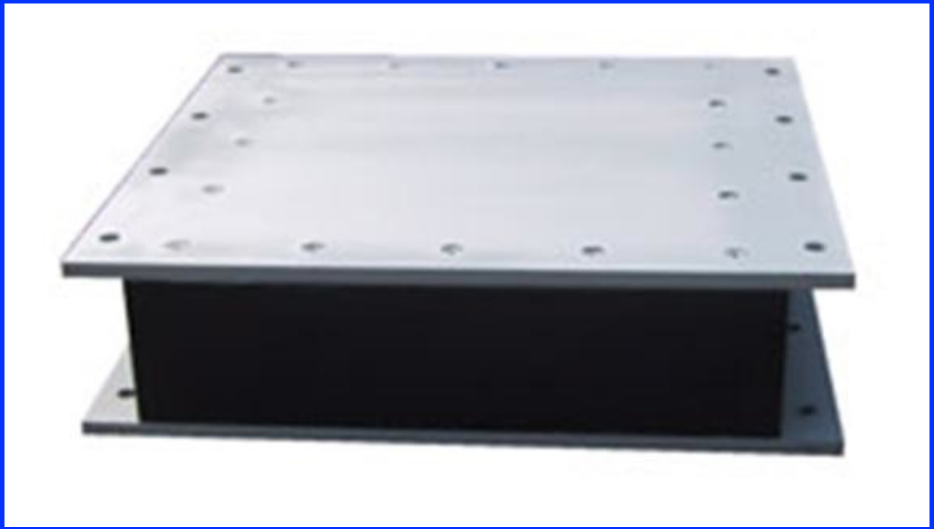
Minimizing the weight may require, for instance, the total transformer power and the total alternate standby sources be subdivided into two or more equipment units.

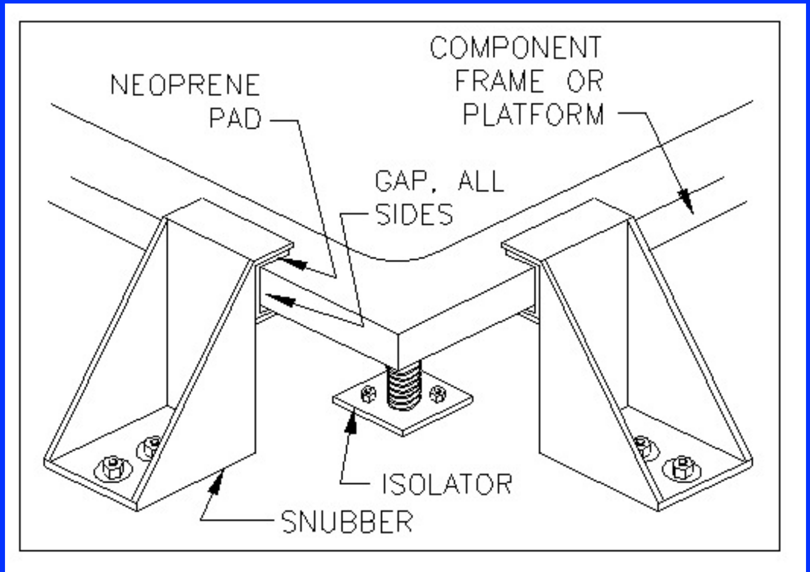
2) Minimize exposure to hazard earthquake



locate the heaviest equipment (transformers, generator sets, motors, main panelboards, UPS) in ground or underground floors ("brush-distribution") *influencing the dislocation of the functional areas in the hospital*

3) **<u>Size and install</u>** components and its anchorages to tolerate or mechanically resist the expected forces (Fp).





Anti seismic devices and snubbers

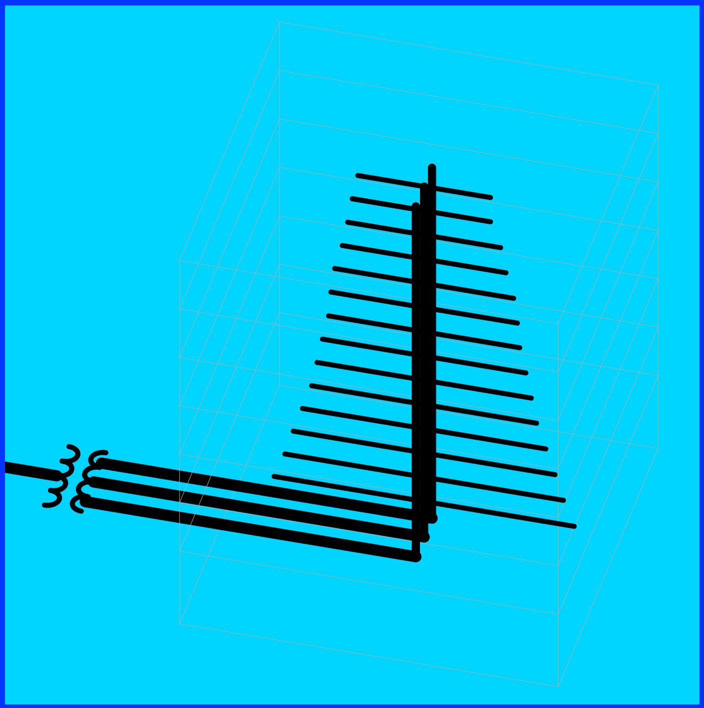
DESIGN AND INSTALLATION : ELECTRICAL CRITERIA

The basic **electrical design** criteria of the electrical power system include:

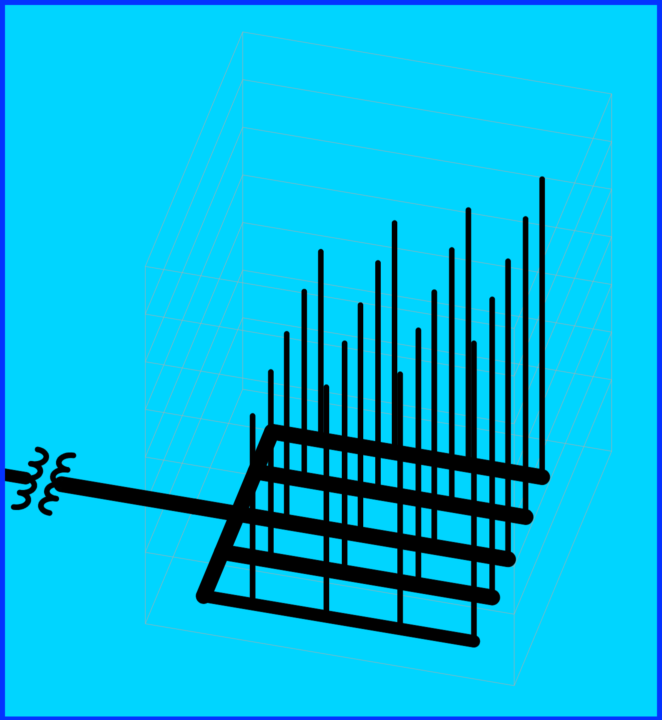
1) **Passive protection** of the components and of the power system (locating components to minimize seismic forces), adopting a **specific power system distribution** that has a seismically efficient structure

2) Install **components adequately** to tolerate or resist the expected forces (Fc).

DESIGN AND INSTALLATION : ELECTRICAL CRITERIA



a)



b)

The normal "tree" structure of a generic power system (a) and the "laid down" structure of a brush distribution system (b) (secondary distribution in "towers")

The criteria of minimizing weight and exposure to the earthquake hazard can be realized:

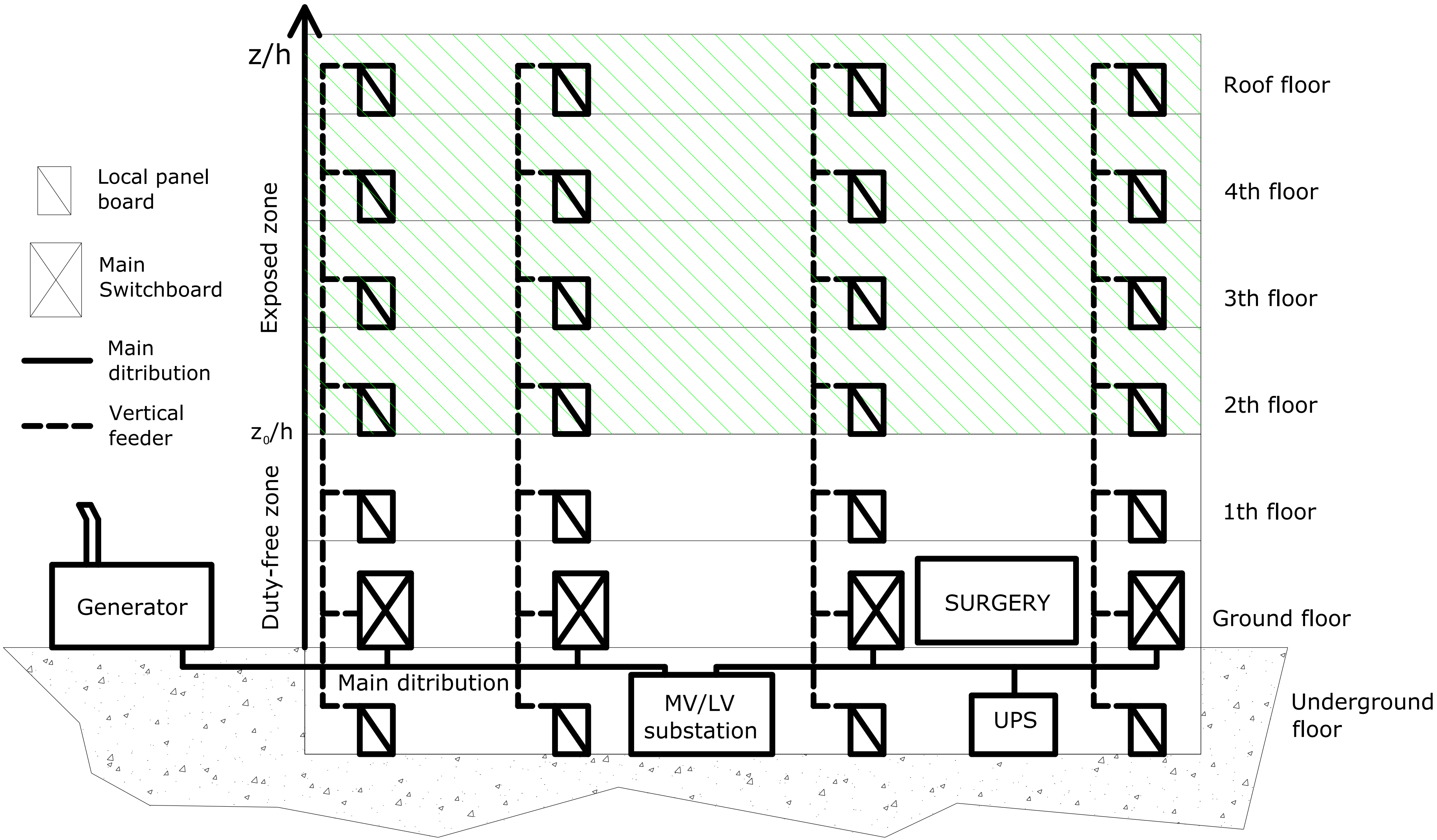
-by laying the distribution system in the "duty-free" zone of buildings (MFS),

-by locating transformers, generator sets and main low voltage distribution as close to the load as possible

-by applying the microsystem approach in configuring the electrical architecture

The Brush-Distribution

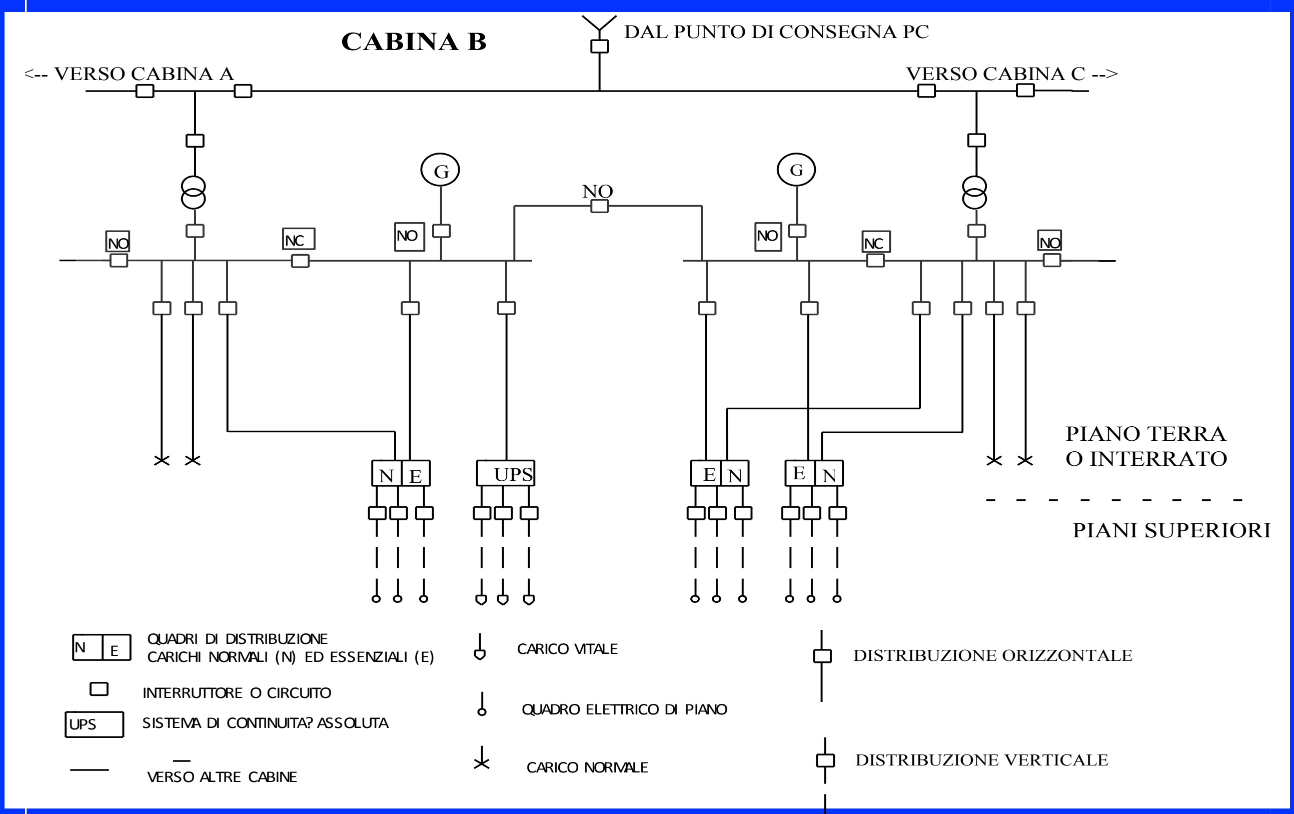
DESIGN AND INSTALLATION : ELECTRICAL CRITERIA



THE BRUSH DISTRIBUTION

DESIGN AND INSTALLATION : ELECTRICAL CRITERIA

Hospitals need an optimal design of power systems with characteristics of high performances useful for a "seismic efficiency"



An issue: Arc Fault Protection

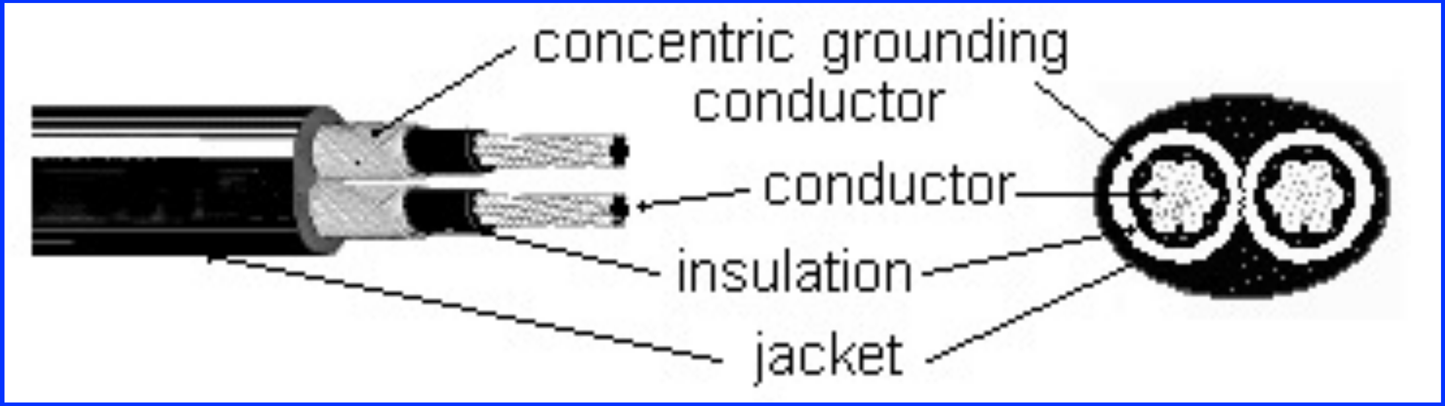
In electrical power systems, ***wiring exposed to mechanical damage*** and other insulation stresses (including wiring not fixed and connected by flexible cords and cables) may have failures characterized by

arcing and burning.

<u>Protection must be provided to prevent the fault from extinguishing itself without being detected and remaining energized</u>.

Complete protection may be achieved by wiring the circuits with special power cables.

Ground-Fault-Forced Cables, GFFCs convert a line-to-line fault into a line to ground fault, that will be detected and protected by ordinary ground fault protective devices (GFPDs).



G. Parise, L. Martirano, R.E. Nabours "Arc Fault Protection of Branch Circuits, Cords and Connected Equipment", IEEE Trans. on IA ,Vol: 40 , May-June 2004.

CONCLUSIONS

Important goals

to coordinate the non structural designing criteria with a layout of the system architecture that avoids or confines as possible intrinsically in a "duty-free" zone (MFS) the seismic exposition and limits the same installation problems (in coordination with the functional "logistic" of the hospital).

A special power distribution, "brush-distribution", has a laid structure suitably for the strategic buildings that are at risk for seismic event (darwinian approach).

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