Reliability and Resilience of Power Supply Systems in Healthcare Infrastructure

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Background

Health infrastructure is a pillar of modern societies, where specialized medical services are provided to a significant amount of people. These infrastructures are especially vulnerable if they are stricken by a catastrophic scenario, so protocols are needed to be implemented. Classical approaches entail risk assessment, project management and predictive maintenance techniques. Some studies provide detailed analyses pointing out the features of a normal operation, the characteristics of the disruption and the way the system fails.

The main concept regarding the correct performance of power supply systems during a continuous period of time is their reliability, which can be defined as the probability of a system to perform correctly during a certain period of time.

The objective of this study is to provide a holistic review of the current studies regarding reliability of power systems, including important design considerations.

Methodology

The resilience term is implemented as a new perspective, and remarkable items which may affect the decision-making processes within health infrastructures are listed out.

As the characterization of available guidelines depends on heterogeneous factors such as geographical conditions, quality of equipment or size of the health infrastructure, the approach that has been made is a generic one, leaving space for singular modifications that may arise.

Considering this, an overview about power systems performance main parameters is carried out through a resilience point of view, comparing the existing data and resources with the new trends tied to the concept of resilience.

Results

According to the existing literature on the evaluation of problems recorded in power supply elements, the list of measurable parameters includes: reliability, availability, security and costs.

Reliability. *Classic trends regarding calculating reliability indices such as probability indices to measure the risk or assurance under specified conditions of configurations, load, time and timespan. Capacity deficiency can be defined with two expressions, by determining the probability of not meeting the annual peak load (P) and the expected energy curtailment (E).*

$$P = \int_{L_{min}}^{L_{max}} P_L(L) P_C(C_j) dL$$

$$E = \sum_{i=1}^{N} L \int_{L_{i\,min}}^{L_{i\,max}} \frac{8760}{N} (L - C) P_{Li}(L) P_{Ci}(C) dC dL$$

L	Density function of an anual peak load
L_{min}	Minium of L
L_{max}	Maximum of L
C_j	Greatest capacity insufficient to meet the load
$P_c(C)$	Probability density function without disruption
$P_L(C)$	Probability density function corresponding to exceeding loads

Another approach involves deviations, calculations in singular buses, optimization models by using Monte Carlo simulations and interruption cost calculations. The expected power loss in the latter can be expressed by:

$$EPNS_i = \frac{\sum_{j=1}^{N} PNS_{ij}}{N}$$

Where PNS_{ij} is the amount of not served demand at the bus "i", considering state "j". N is the number of simulated states. It can be showed in annual terms. Besides, redundancy coefficients can be calculated as:

$$R(t) = 1 - \prod_{i=1}^{n} (1 - R_i(t)); \qquad F(t) = \prod_{i=1}^{n} F_i(t)$$

Being R the reliability of the system and F the probability of failure.

Availability. *The availability of a system can be defined as the ratio between the time where the facility produces energy and the whole period of time. Linked to reliability, availability points out the actual power supply systems that can be used at a certain instant. To assess the availability of a power supply system and to accomplish a compound of decision-making programs, protocols and risk management strategies, it is important to consider the records of the incidents, as well as their duration and severity.*

Renewable power supply systems have been implemented during recent years, and they can play an important role, as they can contribute to satisfy the health infrastructure energy demands. However, these sources often lack availability, as they have intermittent operation. Therefore, they act as good auxiliary items when they are operative, but establishing a baseline upon them could result in severe disruptions if power supply is not guaranteed. To accomplish a resilient power supply system based on renewable energy, new trends have been focused on storing energy excesses to compensate their inherent intermittency.

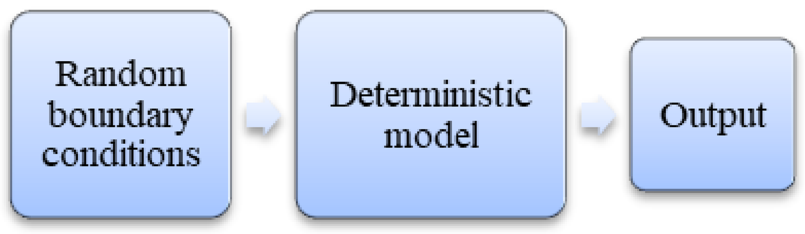
Security. *New trends regarding safety management include terms as robustness, resilience, performance variability linked to outcomes and prophylaxis. Although these concepts are referred to health and clinic issues, security can be addressed through resilience, constantly supervising safety issues while the system recovers its normal operation. Dynamic resilience may be useful to determine the capability and speed of recovery within the power supply systems in a health infrastructure during a disruption state.*

Costs. *Optimization analysis based on reliability costs can be carried out. Minimalization of total costs is tied to finding the optimal value for both utility and consumer costs. This idea can be extrapolated to maintenance, repair and equipment renovation. It is interesting to assess reliability and investment costs curves considering their marginal increments.*

Discussion

The utility of considering these alterations is useful because it helps to identify weak areas where modifications and reinforcements are needed. Chronological trends, complementary statistical studies and operation indices are key factors regarding to reliability assessment. Resilience captures the idea of returning to a normal and steady operation ratio after a disruption scenario, so by adding this to existing models, a scoring system and a new framework can be deduced.

In addition to this, previous predictions can be modelled, proposing a comparison between actual models and previous results, where the actual operating experience is compared to the feedback cumulative results via the previously mentioned indices and statistical approaches. The response of the system can be observed and addressed through control processes, project management techniques and risk assessment tools. Furthermore, system malfunctions in this respect may be assessed through resilience assessment techniques, considering the applicability of qualitative, semi-quantitative and quantitative models. In order to run a simulation, building a deterministic model where input values are randomized may seem a reasonable option.



Conclusions

A review on the main parameters tied to power supply in healthcare systems has been carried out. Resilience has been introduced as one of the trendiest concepts with transversal meanings. Different applicable techniques have been described, and relationships and contributions within classical approaches and new concepts have been addressed in this study.

Acknowledgements

The authors wish to acknowledge to the European Regional Development Fund for the financial support through Research Projects GR18029 linked to the VI Regional Plan for Research, Technical Development and Innovation from the Regional Government of Extremadura (2017-2020).

Unión Europea
Fondo Europeo de Desarrollo Regional: "Una manera de hacer Europa"

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6th Virtual International Conference on Science, Technology and Management in Energy
December 14-15, 2020

eNergetics 2020