

Article

Method of Estimating Uncertainty as a Way to Evaluate Continuity Quality of Power Supply in Hospital Devices

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Abstract: The article presents issues related to the determination of the continuity quality of power supply (CQoPS) for hospital electrical devices. The model describing CQoPS takes into account power redundancy. The uncertainty modeling method based on the certainty factor (CF) of the hypothesis was used to establish the single-valued CQoPS factor. CQoPS modeling takes into account multidimensional quality models and physical stages of power. The quality models take into account seven dimensions that make up CQoPS (availability, appropriate amount, power supply reliability, power quality, assurance, responsiveness, security). The model of power stages includes five of these stages (power generation, delivery to recipient, distribution by recipient, delivery to device, power-consuming device). To date, when designing hospital power systems, the applied reliability indicators revealed limitations because they do not consider all the possible factors influencing the power continuity. Estimating the supply continuity quality with the use of the uncertainty modeling proposed in this article allows for taking into account all possible factors (not just reliability factors) that may affect supply continuity. The presented modeling offers an additional advantage, namely, it allows an expanded evaluation of the hospital supply system and a description using only one indicator. This fact renders the evaluation of the supply system possible for unqualified staff. At the end of the article, some examples of calculations and simulations are presented, thus showing that the applied methods give the expected results.

Keywords: system quality; reliability; supply system; hospital



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1. Introduction

The quality parameter appears more and more frequently in modern service systems. It is perceived as a set of service features, often subjective. Quality can also be related to ensuring the continuity of a specific service. It is often used in relation to the critical elements on which health and life depend. The article presents a method for determining the continuity quality of the power supply of medical devices in their place of installation. The usage of medical devices that require power carries an unknown risk of power loss. Since there is a risk of power loss, we can talk about the uncertainty of power supply continuity, i.e., the continuity quality of power supply (CQoPS) in medical devices used in hospitals.

To date, when designing power systems, the applied reliability indicators revealed limitations because they do not consider all possible factors influencing the continuity of power supply [1–3]. These reliability indicators usually only take into account the reliability of devices and of the components included in the system [4–6]. Estimating the supply continuity quality with the use of the uncertainty modeling proposed in this article allows for taking into account all possible factors (not just reliability factors) that may affect

supply continuity, which are both dependent and independent from each other. Considering independent factors ensures that the appropriate method of estimating uncertainty is selected. This article presents a new approach, which implies the use of uncertainty modeling to estimate the continuity quality of power supply (CQoPS). The applied method is a method used to estimate uncertainty in expert systems, called the certainty factor (CF) of the hypothesis, described and updated in [7,8]. Another method that could be used here is the method based on the DS (from the names of the authors Dempster and Shafer) mathematical evidence theory [9,10] combined with serial modeling used to determine signals from serially connected sensors [11]. Other methods of estimating uncertainty could also be used, but they must allow the modeling of dependent and independent elements (serial and parallel). The CF-based method is sometimes used to model uncertainty in estimating the quality of systems. It has been successfully introduced in various solutions, e.g., for estimating the quality of information [12–14], and has also been presented in the authors' publications [15]. Summarizing, the method of estimating the continuity quality of power supply presented in this article is based on the estimation of uncertainty using the multilayer method described in [16,17]. The method described in this article has already been successfully used in [16] to estimate the quality of information and the usefulness of information and communication technology (ICT) systems [17] and to evaluate simpler models of estimating the continuity quality of power supply in [18].

The method of determining the uncertainty to evaluate the continuity quality can also be employed in devices implemented in transport (e.g., rail traffic control systems) [19–21] or other areas associated with critical systems [22]. It is particularly important because the security level of transport services and the functioning of critical systems depend on this.

The subsequent sections show how the modeling method is defined and how the model becomes multilayered and multidimensional. Section 3 presents a particular modeling solution for a selected, real hospital power supply system. The next section introduces the CF method, which was used as a mechanism for calculating the uncertainty in the CQoPS model. In Sections 5 and 6, the calculations for the exemplary model and simulations for different initial values of the CQoPS model are exhibited, respectively. Finally, Section 6 presents a summary and describes the benefits of using the method presented in the article.

2. State of the Art

Systems intended to power medical devices used in hospitals should have much better parameters compared to those which power devices in office or home facilities. This is due to the fact that medical equipment has a significant impact on the health of hospitalized people, and is often life sustaining. For this reason, hospital power systems are required to be reliable.

To ensure the reliability of hospital power systems, redundant structures are adopted, among other things. The redundancy of the primary power source can be achieved by using a backup power source, such as a standby generator. An example of a facility where this type of solution is provided is base stations of digital cellular telephony utilized in traffic management (e.g., in rail transport). The specificity of rail transport management systems requires electronic devices for base stations. The study described in [23], which includes analyses and simulations (of both power supply reliability and economical aspects), confirms the validity of using such solutions.

Apart from using backup power sources in the form of a standby generator, it is also necessary to simultaneously workout solutions that enable the collection of power. Most commonly used are battery packs of suitably large capacities. This enables power to be stored and its subsequent use to power medical devices used in hospitals (until the standby generator starts to supply power with appropriate parameters). The study described in [24] presents various design solutions used to store power. This significantly increases the level of power security.

When assessing the reliability, operation and quality of hospital power systems, one should also take into account the subsystems used to control and manage power networks. The study described in [25] presents the issues related to various ICT solutions employed to monitor power systems which increase the safety of power systems. At the same time, the applied diagnostics enable defining the location of failures which cause a state of partial fitness or unfitness of individual power subsystems.

Nowadays, with a relatively high level of cyber-terrorist threats, the issue of ensuring an adequate level of ICT security for hospital power systems is equally very important. The study described in [26] involves insight into the area of analyzing the security level of the computer network used for power supply control. Such factors can be included in the method developed by the authors and described in this article.

When considering the power supply for medical devices used in hospitals, one should not only adopt an approach that takes into account reliability and exploitation indicators [27], but also take a broader view of the functioning power systems. Therefore, the issue of ensuring electromagnetic compatibility of the applied electrical and electronic devices is vital [28,29].

As mentioned earlier, medical equipment often requires a continuous power supply. This is secured by providing redundancy of power sources. In the case of hospitals, these are usually accumulator batteries or engine generators. For the purpose of this article, the authors adopted a redundant power supply system with a stand-by power supply unit but without delving into its technical details. A rough diagram of the analyzed power supply system is presented in Figure 1. It is a block diagram.

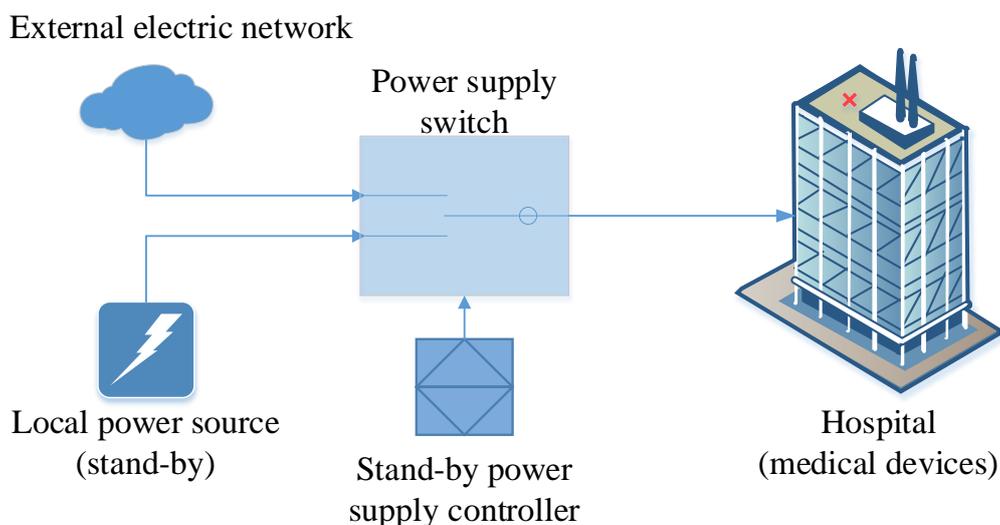


Figure 1. Block diagram of the power supply system of medical equipment in a hospital.

Quality can be described in many ways. There are standards that describe quality, such as ISO 9000. However, these definitions are quantified for a specific application as a standard. This article adapts the concept of quality perception based on reports and publications related to the Massachusetts Institute of Technology Information Quality (MITIQ) Program [30]. This is where, among other things, an information quality model based on sixteen dimensions and over a hundred of their features was devised [31]. On the basis of research and analysis conducted at MITIQ [30], as well as on our own study [15–18,32], the CQoPS model was based on quality dimensions. Such an adaptation is a completely new approach to the assessment of power systems. This kind of assessment takes into account not only the reliability elements but also many others, which may be dependent as well as independent and subjective. Many dimensions of the CQoPS were taken into account, as shown in Figure 2. Here are these dimensions:

1. Availability (D_{av})—a dimension that defines the possibility of energy being provided on demand, at a given time and by an authorized process. This dimension is directly related to energy security.
2. Appropriate amount (D_{aa})—a dimension that determines how much energy is adequate to complete the task, and at the same time indicates that the amount is sufficient and that energy surplus could reduce the quality.
3. Power supply reliability (D_{psr})—a dimension that determines that the reliability of the power system is at an appropriate level to perform a particular task.
4. Power quality (D_{pq})—a dimension that defines the supplied power quality.
5. Assurance (D_{as})—a dimension that determines the assurance that energy will be provided to carry out the task.
6. Responsiveness (D_{res})—a dimension that determines requested energy availability by the system and whether the supply system will meet this demand.
7. Security (D_{se})—a dimension that determines adequate protection of the power supply systems against external factors.

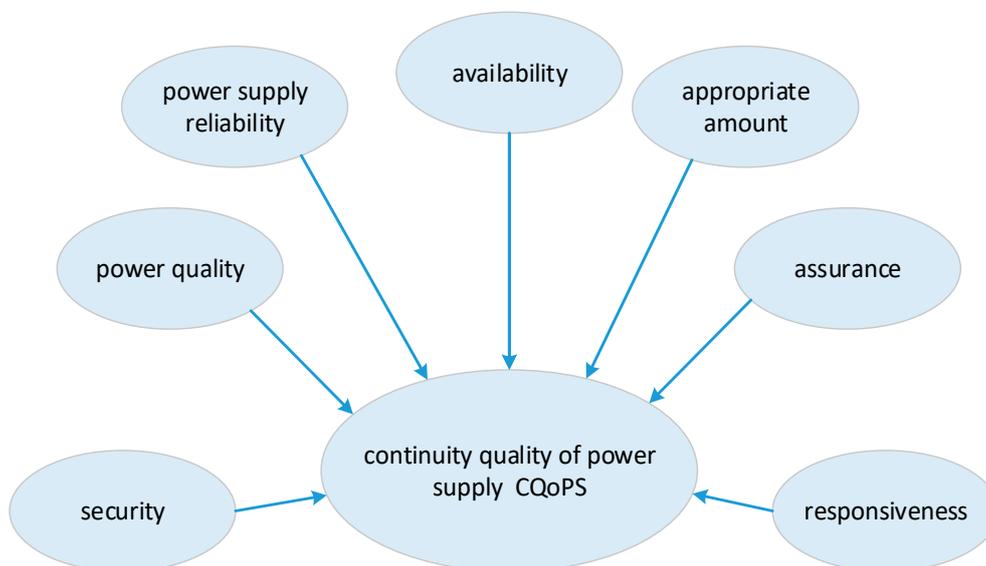


Figure 2. CQoPS dimensions.

Each of the abovementioned dimensions can be described with an additional layer, which can contain the dimension features. Thus, a multilayer CQoPS dimension model can be created. Dimension features can be the generally accepted parameters, for example, for the D_{pq} dimension, parameters describing the quality of electricity can be added as features.

Scientific considerations allow for the adoption of other dimensions, such as self-reliance, which consists in maximizing the use of locally generated energy and minimizing the import of energy from the external system [33,34]. In this article, the authors have limited themselves to the seven dimensions given. Further dimensions will be taken into account in future publications.

Figure 2 presents all the abovementioned dimensions which affect CQoPS. Each of the dimensions has a direct impact on CQoPS. Assuming that each dimension value (dimension factor) can vary from 0 to 1, a dimension that does not affect CQoPS will have the value 1 and a dimension significantly lowering CQoPS will have the value 0. Adopting the value range [0, 1] enables us to calculate quality with statistical methods (e.g., the probability of error P_e can be treated as the dimension factor. Power quality = $1 - P_e$) but also with the methods of estimating uncertainty, such as mathematical evidence based on the

Dampster–Shafer theory or CF modeling [30,32]. In general, CQoPS consists of many of the abovementioned dimensions.

In general, it can be assumed that the CQoPS measure consists of many repetitions of the dimensions presented above. Thus, CQoPS can be described by the formula:

$$\text{CQoPS} = f(D_1, D_2, \dots, D_m) \quad (1)$$

where:

- m —number of dimensions, quality components (equals 7 in accordance with the number of the abovementioned dimensions),
- D —a variable defining the influence of a given dimension (e.g., value in the range [0, 1]).

Having described the quality dimensions that can be used in assessing the continuity quality of the power supply, it is necessary to explain the physical stages of power from generation to consumption (Figure 3). These are the stages:

1. Power generation. Power source—power plants (of various types), power backup system [35], local solar systems, wind power plant [36], diesel generators.
2. Delivery to the recipient. Power transport systems are typically a wiring system based on electrical conductors.
3. Distribution by the recipient. The power distribution system is typically the cabling network of the recipient building.
4. Delivery to the device. Supplying power to the device is not only about cables, but also security and frequently about power adapters.
5. Power-consuming device.

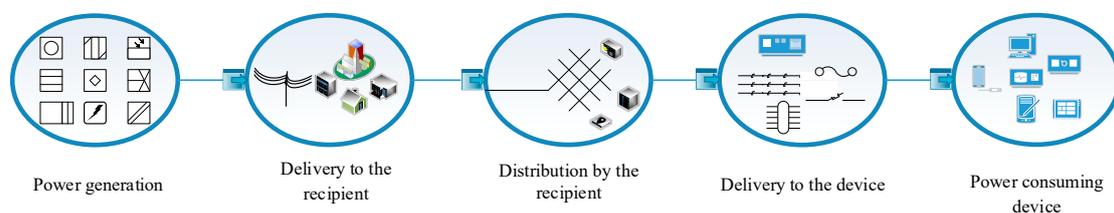


Figure 3. Physical stages of power.

The demonstrated quality dimensions can also be applied to devices which take part in the particular stages of energy distribution (e.g., demand side management (DSM) techniques [37,38]). In this article, the method will be applied on a more general level. On the whole, this method can be used to evaluate various systems, but the dimensions and states should be selected appropriately for the specific assessment. An example of the application of this type of modeling may be a publication of one of the co-authors [32], in which the author used this type of modeling to assess the information quality of ICT systems in transport.

Taking into account the physical stages of power, Formula (1) should be expanded into the form of a table, as shown below:

$$\text{CQoPS} = \begin{bmatrix} D_{11} & \cdots & D_{1m} \\ \vdots & \ddots & \vdots \\ D_{n1} & \cdots & D_{nm} \end{bmatrix} \quad (2)$$

where:

- m —number of dimensions, components of supply continuity information quality: equals 7 in this model (Figure 2),
- n —number of physical stages of power transmission: equals 5 (Figure 3),
- D —a variable defining the influence of a given dimension (e.g., value in the range [0, 1]).

The modeling of this method can be achieved using simple directional graphs, whereas the determination of factors of the dimensions and of the stages can be achieved by applying uncertainty modeling. This type of modeling is presented in the next section.

3. Description of the Model of Evaluating the Continuity Quality of Power Supply

The model of evaluating CQoPS will be based on observing factors which influence power supply continuity.

The methodology of conduct when creating a model is defined as the following four steps:

Step 1: The choice of the supply states and their dependencies and independencies. In the example below, the intermediate hypotheses h_1 and h_2 are independent, whereas the remaining intermediate ones are dependent.

Step 2: The choice of CQoPS dimensions, which sufficiently and fully represent the elements of the system evaluation. Dimension factors are related to observations. If the factors are described with many features with this step, these features must be accounted for.

Step 3: Creation of a multilayer and multidimensional CQoPS model. Observations are assigned to each of the intermediate hypotheses. One of these observations is positive. It is the one that is expected. The rest of the observations are negative within one intermediate hypothesis. This division of observations results from the chosen calculation method, in this case, the CF uncertainty modeling.

Step 4: Assigning the observation values and determining subsequent intermediate hypotheses and the final hypothesis. The final hypothesis is the CQoPS value. This step was handled in Section 5.

There are five selected independent groups of factors, which influence the power supply continuity of devices.

1. Factors connected with the main source of supply. In this case, the source could be the power installation or a local power-generating unit. This group of factors will include power supply reliability [39,40], power availability (if sufficient power is provided) [41] and service error. Factors connected with the source of supply will influence the value of intermediate hypothesis h_1 .
2. Factors connected with a stand-by source of supply. In this case, the source could be the power installation or a local power-generating unit. This group of factors will include power supply reliability [39,40], power availability (if sufficient power is provided) [41] and service error. Factors connected with the source of supply will influence the value of intermediate hypothesis h_2 .
3. Factors connected with power transmission. In this case, the factors include the adequacy of the applied media, their reliability (reliability structures [42–46]), construction error (human) and power loss. Factors connected with power transmission will influence the value of intermediate hypothesis h_3 .
4. Factors connected with electrical safety devices. In this case, the factors include the adequacy of the fuses, their reliability and human error [47–52]. Factors connected with electrical safety devices will influence the value of intermediate hypothesis h_4 .
5. Other factors connected with fortuitous events. In this case, the factors include cataclysms. Factors connected with fortuitous events will influence the value of intermediate hypothesis h_5 .

The final hypothesis is h —power supply works well. It consists of dependent intermediate hypotheses (Figure 4).

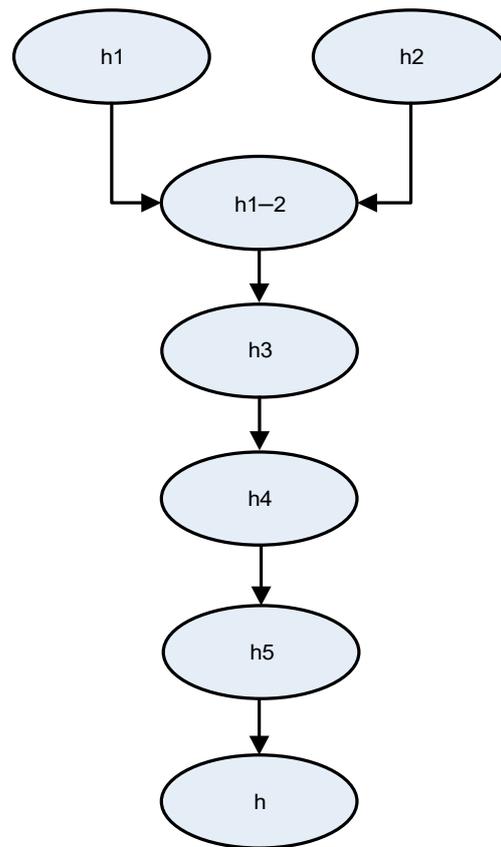


Figure 4. Model for hypothesis h.

- h1—Main source of supply provides electrical power. On the basis of observation e1.
- h2—Stand-by source of supply provides power. On the basis of observation e2.
- h3—Systems of power transmission function correctly. On the basis of observation e3.
- h4—Efficiency of security systems is ensured. On the basis of observation e4.
- h5—No fortuitous event affects the supply of power. On the basis of observation e5.

Each of the intermediate hypotheses is formulated on the basis of observation results from observing factors in every particular category.

The intermediate hypothesis formulated on the basis of observation e1 consists of the following independent observations:

- e1.1—Supply system functions correctly.
- e1.2—Failure of external supply system ($1 - D_{psr}$).
- e1.3—Lack of external power ($1 - D_{se}$).

The intermediate hypothesis formulated on the basis of observation e2 consists of the following independent observations:

- e2.1—Stand-by power supply system functions correctly.
- e2.2—Failure of elements providing stand-by supply ($1 - D_{psr}$).
- e2.3—Power shortage from stand-by source (e.g., poorly designed supply network) ($1 - D_{aa}$).

The intermediate hypothesis formulated on the basis of observation e3 consists of the following independent observations:

- e3.1—Supply system functions correctly.
- e3.2—Damage to the elements providing supply ($1 - D_{psr}$).
- e3.3—Power shortage (e.g., poorly designed supply network; wrong wire intersection) ($1 - D_{av}$).

The intermediate hypothesis formulated on the basis of observation e4 consists of the following independent observations:

- e4.1—security system functions correctly.
- e4.2—Inadequate security systems, which broke down ($1 - D_{psr}$).
- e4.3—Incompatible or poorly designed security system ($1 - D_{se}$).

The intermediate hypothesis formulated on the basis of observation e5 consists of the following independent observations:

- e5.1—Supply system functions correctly.
- e5.2—Breakdown due to cataclysm ($1 - D_{psr}$).
- e5.3—Breakdown due to human error ($1 - D_{as}$).

All the abovementioned observations regard a system with redundant power supply sources.

Figure 5 demonstrates a graph of the model for intermediate hypothesis h1. Graphs of the consecutive intermediate hypotheses (except h1–2) would look alike. Figure 6 demonstrates a graph of the model for intermediate hypotheses h1–2.

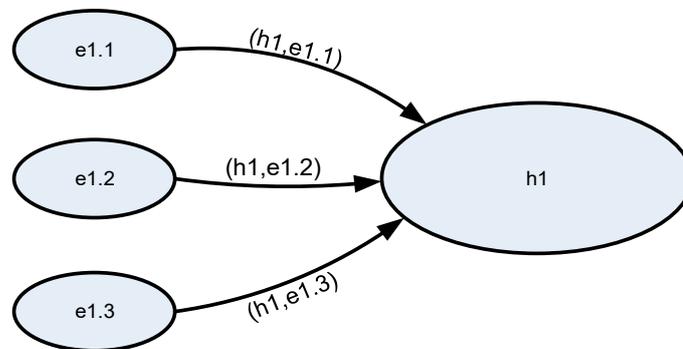


Figure 5. Model for intermediate hypothesis h1.

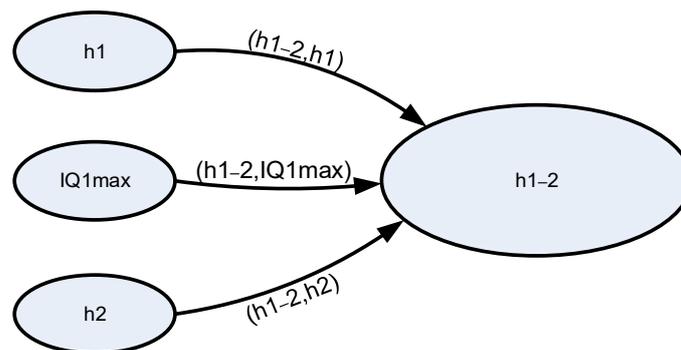


Figure 6. Model for intermediate hypotheses h1–2 (IQ1max is the maximum value which can be achieved by the factor of the hypothesis [32]).

4. Uncertainty Modeling

Methods of evaluating uncertainty can be applied to determine CQoPS. However, these methods must enable calculations of dependent and independent methods. One of these methods is the one mentioned in the Introduction, namely, the method of determining the certainty factor (CF) of the hypothesis [7,8]. The other methods, which can be applied, are the ones which allow uncertainty modeling of dependent and independent elements, e.g., a hybrid method devised by one of the authors of this paper [15,16].

4.1. Certainty Factor of Hypothesis Modeling

As it has already been mentioned that a convenient model to describe information quality can be the certainty factor (CF) of hypothesis modeling. It is assumed that the value of this factor would be the direct value indicating the quality of information related to the specific hypothesis, e.g., a moving vehicle in a scene observed by a camera. Just the fact that the car is moving forms information about the car. At the same time, it is a hypothesis deduced on the basis of the premises analysed by the system of visual surveillance. The CF of this hypothesis is the information quality measure of the car movement.

A reliable presentation requires describing the rudiments of the method [7,8]. The formal simplified description of CF is as follows:

$$CF(s) = MB(s) - MD(s) \quad (3)$$

where the following stand for:

- CF—certainty factor;
- MB—measure of belief;
- MD—measure of disbelief;
- s—hypothesis based on some information from observation. In the original method from [7,8], the word “information” is applied here, but the modeling presented here is based on observations, and more specifically on information obtained from these observations.

It is important to remember that:

$$MB \rightarrow \langle 0, 1 \rangle; MD \rightarrow \langle 0, 1 \rangle; CF \in \langle -1, 1 \rangle \quad (4)$$

The interpretation of the measure of belief MB and disbelief MD in connection with probability could be as follows:

$$CF(s) \begin{cases} 1 & P(s) = 1 \\ MB(s) & P(s) > P(\neg s) \\ 0 & P(s) = P(\neg s) \\ -MD(s) & P(s) < P(\neg s) \\ -1 & P(s) = 0 \end{cases} \quad (5)$$

where the following stand for:

- P—probability;
- s—hypothesis based on some information from observation.

However, as has been mentioned earlier, it is not our purpose to determine probability because the quality measure is supposed to be connected with the final hypothesis CF model.

There are many varieties of CF modeling, therefore, we present basic the dependencies [8] used in this article.

4.1.1. Basic Parallel Model

The formula for calculating the passage according to Figure 7 between two parallel observations and the hypothesis is as follows [8]:

$$CF(h, e1, e2) \begin{cases} CF(h, e1) + CF(h, e2) - CF(h, e1) \cdot CF(h, e2) & \text{if } CF(h, e1) \geq 0 \text{ and } CF(h, e2) \geq 0 \\ \frac{CF(h, e1) + CF(h, e2)}{1 - \min(|CF(h, e1)|, |CF(h, e2)|)} & \text{if } (CF(h, e1) \cdot CF(h, e2)) < 0 \\ CF(h, e1) + CF(h, e2) + CF(h, e1) \cdot CF(h, e2) & \text{if } CF(h, e1) < 0 \text{ and } CF(h, e2) < 0 \end{cases} \quad (6)$$

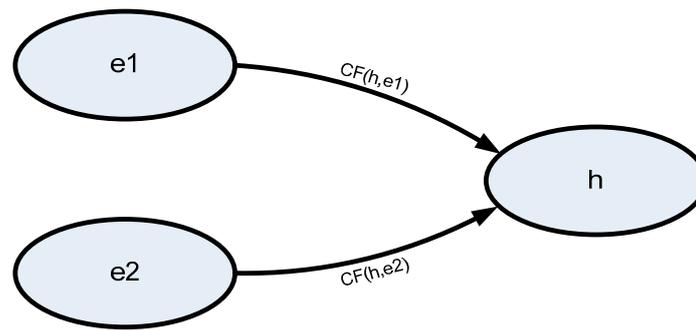


Figure 7. Parallel passages between two observations and the hypothesis.

4.1.2. Basic Serial Model

In case of a serial model for positive values (and this will appear in the modeling described later), according to Figure 8, the following dependencies were used [8]:

$$CF(h, e1, e2) \begin{cases} CF(e2, e1) \cdot CF(h, e2) & \text{if } CF(e2, e1) > 0 \\ 0 & \text{if } CF(e2, e1) \leq 0 \end{cases} \quad (7)$$



Figure 8. Serial passages between two observations and the hypothesis.

Both connections, the parallel and serial ones, can be reduced to one single branch, as shown in Figure 9. This feature allows simplified calculations in the model, which will be presented in the next section.

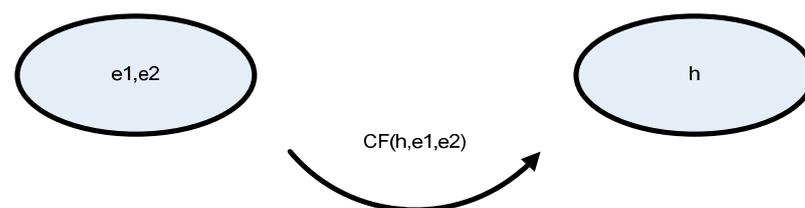


Figure 9. The result of the simplification on the basis of Formulas (6) and (7).

In the next part of the paper, only the parallel model will be adopted. We assume that the CF of the final hypothesis will be the value of the CQoPS.

5. Applying the Hybrid Method in Evaluating CQoPS Modeling

The observation factor values for all intermediate hypotheses are specified in Tables 1–5. These values are exemplary and are used to demonstrate the potential of the methods presented in this article. The observation factors, which have a negative impact on the quality, have a negative value. All values introduced in this article are dimensionless in the physical sense. This is due to the fact that they are observation factors, which can be both the probability and the survey result normalized to the [0, 1] value range.

Table 1. Assignment of particular values for h1. Prepared by the authors on the basis of [2,3,53,54].

Observation	Value
e1.1	0.98
e1.2	−0.1
e1.3	−0.02

Table 2. Assignment of particular values for h2. Prepared by the authors on the basis of [2,3,53,55,56].

Observation	Value
e2.1	0.99
e2.2	−0.08
e2.3	−0.03

Table 3. Assignment of particular values for h3. Prepared by the authors on the basis of [2,53,55,56].

Observation	Value
e3.1	0.998
e3.2	−0.05
e3.3	−0.0005

Table 4. Assignment of particular values for h4. Prepared by the authors as an example. Prepared by the authors on the basis of [2,53,57,58].

Observation	Value
e4.1	0.985
e4.2	−0.03
e4.3	−0.01

Table 5. Assignment of particular values for h5. Prepared by the authors as an example. Prepared by the authors on the basis of [2,53,57,58].

Observation	Value
e5.1	0.999
e5.2	−0.00001
e5.3	−0.02

The value of 0.9999 was assumed for the limiter of the maximum value of IQ1max. On the basis of Formulas (6) and (7), the CQoPS value equals 0.9925.

6. Simulation and Comparison of Results

The influence of the observation factors on the intermediate hypotheses and on the final hypothesis was tested by simulation. A series of simulations was performed, the results of which are presented below in the form of graphs. One of the authors wrote a special computer program for this simulation.

Figure 10 shows the influence of the observation factors related to the correct operation of the main (external) power supply. The range of the e1.1 factor was from 0.5 to 0.99.

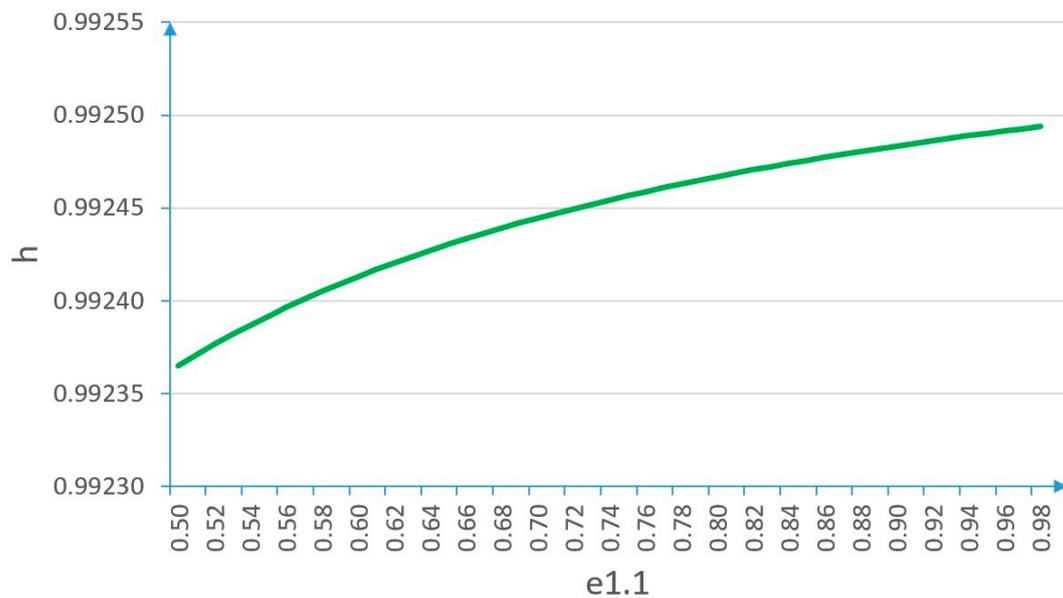


Figure 10. CQoPS simulation result in the e1.1 observation function. The result of the operation of software written by one of the authors of the article.

Figure 11 shows the influence of the observation factors related to the correct operation of the backup (local) power supply. The range of the e2.1 factor was from 0.5 to 0.99.

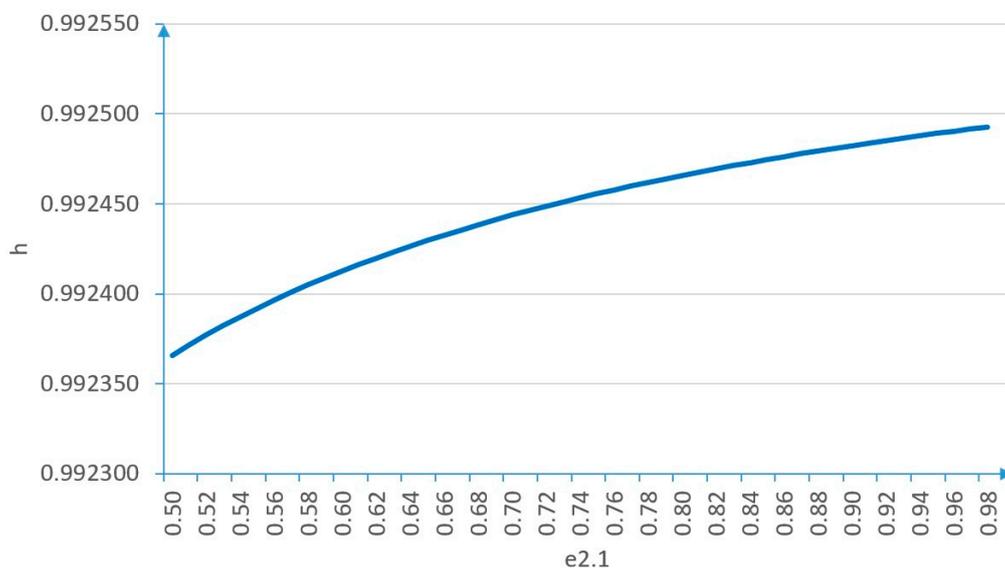


Figure 11. CQoPS simulation result in the e2.1 observation function. The result of the operation of software written by one of the authors of the article.

Figure 12 shows the impact of the values of the observation factors related to the incorrect operation of the backup (local) power supply using the e2.2 observation. The range of the e2.2 factor was from -0.1 to -0.01 .

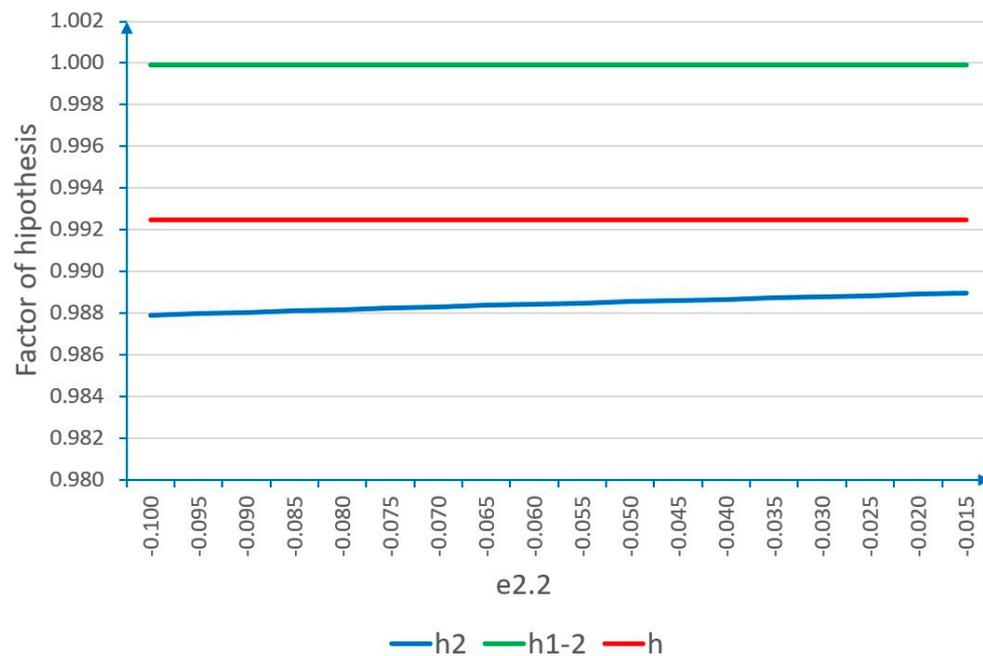


Figure 12. The result of the CQoPS simulation and indirect hypotheses in the e2.2 factor function. The result of the operation of software written by one of the authors of the article.

When analyzing the simulation results, it can be concluded that the first two graphs (Figures 10 and 11) show a typical course for qualitative graphs as a function of factors improving this quality. A characteristic element of such quality graphs is the pursuit of perfection at infinity [32]. However, the graph in Figure 12 shows the negative impact of observations, indicating a reduction in quality at the subsequent stages of its determination (subsequent levels of hypotheses). The nature of the graphs is as expected due to the fact that the observation factor has a huge impact on the near intermediate hypotheses and a very little one on the final hypothesis, which in this case is the CQoPS value.

From the practical side, the simulations show that with the increase in the observation factors, the CQoPS value increases less and less. This means that it is easy to improve CQoPS at low values but difficult at high values. Translating this into cost, it is more expensive to improve CQoPS from, e.g., 0.91 to 0.92, than from 0.83 to 0.84. However, these results are in line with an overall qualitative model whose end value pursues excellence. Such a general qualitative model was described by one of the co-authors in [32].

7. Summary

The continuity of power supply is an important factor in protecting the lives of hospital patients. This article describes a method which enables evaluating the continuity quality of power supply and reducing it to a single indicator. It is presented as a method of evaluating the CQoPS of systems with source redundancy. In order to determine CQoPS, uncertainty modeling was applied based on the method presented at the ESREL 2015 conference but also in the monograph of one of the authors and based on the CF of the hypothesis. The genealogy of the proposed method was presented. Sample calculations and simulations were provided. The simulation allowed us to show how the selected values of the observation factors affect the CQoPS value. Thanks to the simulation, it was shown that the observation factors have an influence on the final CQoPS result and that this influence has an expected course. The simulation software was written for the purposes of this article.

When designing power systems, reliability indicators are usually applied. Yet they reveal limitations because they do not consider all possible factors which influence the continuity of power supply. Estimating the supply continuity quality with the use of the

uncertainty modeling proposed in this article allows for taking into account all possible factors (not just the ones characterizing reliability) that may affect supply continuity. An advantage of the devised method is that the presented modeling enables an expanded evaluation of the hospital supply system and a description using only one indicator. The result in this form becomes the power supply evaluation which can be used even by unqualified staff.

The qualitative model used in the proposed method also takes into account the non-linear impact of efforts to improve quality on its value. This dependency is the most expected influence that describes the real dependencies very well.

The main disadvantage of the method presented in this article is the difficulty in determining the observation factors.

The next step in the authors' research in this field will be the selection of a model calibration method for determining CQoPS.

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