Methodology for Conducting Power Quality Studies in Health Care Institutions

Metodología para Realizar Estudios de Calidad de Potencia en Instituciones de Asistencia Médica

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RECIBIDO: abril 21, 2017. ACEPTADO: junio 02, 2017. VERSIÓN FINAL: noviembre 01, 2017

ABSTRACT

This paper presents a methodology for conducting power quality (PQ) studies in health care institutions integrating aspects related to the electrical network and the electromagnetic susceptibility and immunity levels of the equipment use in this facilities (medical equipment). In this methodology, explains step by step the required activities that must be carried out with the aim to reduce the possibility of errors in the execution of the study of PQ. The methodology proposed is composed by seven steps (stages), for which the international standards IEEE 1159, IEEE 519, IEC 61000, IEC 60601 and the Colombian standards NTC 2050 and NTC 5001 were taken into account. In addition, some procedures and recommendations raised by other institutions were integrated to the process.

KEYWORDS: electromagnetic compatibility, electrical facilities, electromagnetic immunity, electromagnetic susceptibility, health care institutions, medical equipment, power quality,

RESUMEN

Este artículo presenta una metodología para realizar estudios de calidad de potencia (PQ) en instituciones de asistencia médica integrando aspectos relacionados con la red eléctrica y los niveles de susceptibilidad e inmunidad electromagnética propios de los equipos usados en estas instalaciones (equipos médicos). En esta metodología se explican paso a paso las actividades que se deben realizar con el objetivo de reducir la posibilidad de errores en la ejecución del estudio de PQ. La metodología propuesta está compuesta por siete pasos (etapas), para los cuales se tuvieron en cuenta los estándares internacionales IEEE 1159, IEEE 519, IEC61000, IEC60601 y las normas colombianas NTC 2050 y NTC 5001. Adicionalmente, se integraron al proceso algunos procedimientos y recomendaciones planteados por otras instituciones.

PALABRAS CLAVE: calidad de potencia, compatibilidad electromagnética, equipos médicos, inmunidad electromagnética, instalaciones eléctricas, instituciones de asistencia médico, susceptibilidad electromagnética

1. INTRODUCTION

Medical equipment and instruments used in surgery rooms are devices required to provide life support to patients who are in critical or vulnerable conditions during surgeries. The failure or damage of one of these equipment can have negative consequences for the health or even for the life of the patient. For these reason, it is of vital importance to ensure the proper functioning of this type of devices.

The equipment using in medical facilities are susceptible to failures and electrical disturbances with consequences such as reboots, loss of information, temporal loos of functionality and even permanent damage. Several studies have reported cases in which, due to this type of

equipment failures, the patients and medical personnel have been victims of accidents and injuries of consideration. In Colombia, with the entry into force of decree 4725/2005, INVIMA (National Institute for Drugs Surveillance) have been collecting information of incidents related to the use of electromedical devices. In this way, INVIMA received a first report of 318 cases between 2005 and 2007 and a second report of 617 cases in the period 2007-2015 [1].

Although there are technical standards such as IEEE 1159 (*Recommended Practice for Monitoring Electrical Power Quality*) [2] that guarantee the proper functioning of hospital electrical facilities, their compliance is not always sufficient to avoid failures. This is because the disturbance levels allowed in the electrical network may be greater than the levels of electromagnetic susceptibility and immunity of each equipment. An additional problem is that requirements for the facilities are not fulfilled in some cases, mainly, when modifications or expansions are made in the hospital electrical network.

While the standard IEEE 1159 recommends conducting power quality (PQ) studies in a periodic way (annual), these are restricted to compliance of the network conditions and they are not included the equipment performance. Due to this, although the recommendations of this standard are strictly followed, the risk for the equipment and other devices with low levels of electromagnetic susceptibility and immunity (with respect to the facilities) are still present [2].

Under this consideration, this paper proposes a methodology for conducting PQ studies in health care institutions and hospital buildings, taking into account the standards and recommendations given by institutions such as IEEE, IEC, NFPA and ICONTEC, among others. This methodology allows a detailed analysis of the disturbances that may affect the medical equipment including their electromagnetic compatibility (EMC) limits. In this way, it is possible to achieve better results in the PQ analysis for this type of facilities, increasing the effectivity of the results and reducing the risk levels and the failure rate of equipment. The most important, safety conditions for patients and medical personnel who interact with the equipment and the electrical network are improve.

2. REGULATORY FRAME WORK

Hospital facilities are considered as highly sensitive facilities because of the function they perform and the fragility of medical equipment used. For this reason, there are standards that require strict compliance with certain design requirements of the installation, which ensure not only the continuity of the electrical service, but also the correct operation of equipment under specific conditions. These standards are classified into design rules, standards for network operation and EMC standards.

Taking into account the references examined, it was found that the standards NTC 2050 [3] and ANSI/IEEE 602 [4] are related with the design of hospital facilities. Regarding the standards related with the operation of the network, NFPA 99 [5], NTC 5001 [6], IEC 60601-2 [7] and IEEE 519 [8] indicate the way of measuring the electrical parameters within the installation, the periodicity and the aspects to evaluate the performance of the protection and backup equipment. In addition, these standards present the limits for the different types of disturbances that can ocurr in the electrical networks. Finally, the IEC 61000-4-7 [9] and IEEE 1346 [10] standards are used for testing and evaluation of harmonics, inter-harmonics and compatibility requeriments for electronic sensible equipment (including medical equipment).

3. REQUIREMENTS FOR HOSPITAL ELECTRICAL FACILITIES

Hospital electrical facilities must comply with high levels of reliability and reduce the levels of electrical disturbances in order to guarantee continuity of service and protection of sensitive equipment. The requirements for this type of facilities are defined by the standards IEEE 519, ANSI/IEEE 602, IEC 61601 and NTC 2050. The most important aspects are described below.

3.1. Power supplies

The Colombian standard NTC 2050 establishes that two independent power supplies are required in health care services. The main source is used for the normal supply, which feeds the entire electrical system, and the second one is an alternative source used to supply energy when an interruption occurs in the normal power supply system [3].

3.2. Classification of loads

The ANSI/IEEE 602 defines three groups of electrical loads classified according to the level of electromagnetic susceptibility. The first group includes loads such as heating, ventilation, air-conditioned, water and gas pumps, elevators and escalators. The second group includes functional loads such as kitchens, communication systems, office equipment and data processing equipment. Finally, the third group is related with the equipment for medical porpoises including X-

ray systems, clinical laboratory, surgical, therapy and intensive care equipment [4].

3.3. Classification of circuits

According to NTC 2050 hospital facilities require independent circuits for each group of loads, and classify the loads in non-essential loads and essential or critical loads [5], [10]. This classification reduces interference problems in zones where sensitive elements are placed. These zones are intensive care and surgery rooms, among others [3], [5].

3.4. Automatic commutation system

The standard NTC 2050 indicates that hospital facilities must have an automatic system that switches the power supplies of the essential system when there is a failure condition or an interruption of the energy service. This commutation system guaranties the service continuity and the adequate operation of all sensitive equipment [3]. The connection scheme for the commutation system and the electrical system of a hospital are shown in Figure 1.

3.5. Protection against overvoltages

The hospital installations require protection zones taking in to account the features of the electromagnetic disturbances and the immunity levels of the electromedical equipment. For this reason, in the electrical facilities of health care institutions the following activities must be conducted [3]:

- Connection of surge arresters to the main network
- Use systems with UPS (uninterruptible power supply) to decoupled the essential systems from the rest of loads
- Use of isolation transformers to decouple the most sensitive equipment from the circuit that feeds the essential system
- Installing of specific UPS devices to protect the most sensitive equipment against the electrical disturbances

3.6. Uninterruptible power system

It is necessary to use a system with on-line UPSs to connect the external network with the essential system. This connection reduces the risk of interruption or disconnection of loads during the commutation of the power supply sources. The use of UPSs also reduces the PQ problems produced by external loads and must have enough capacity to maintain the energy supply permanently until the main power supply is restored [3], [11].

4. PROPOSED METHODOLOGY

The methodology presented in this section allows to perform PQ studies accurately, indicating the activities to be conducted and the analysis process required to identify and evaluate electromagnetic disturbances in medical facilities. In addition, it allows establishing the effect of these disturbances in sensitive equipment taking into account their levels of susceptibility and immunity.

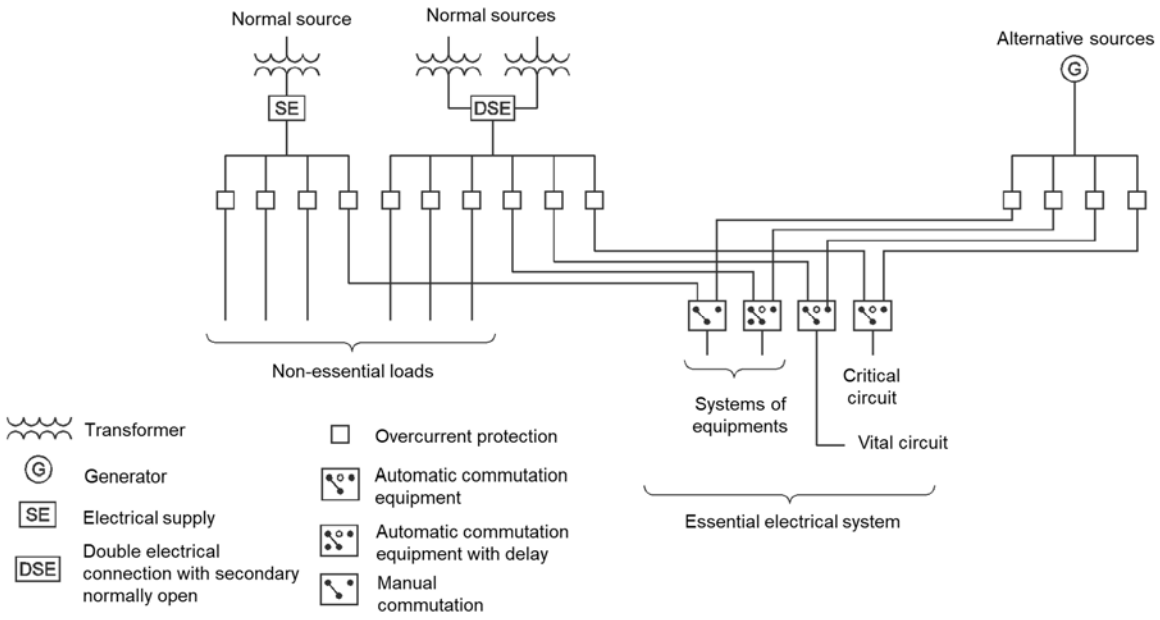

Figure 1. Typical electrical network of a hospital
Source: Adapted from NTC 2050 [3]

The methodology was developed taking in account the IEEE 1159 standard, some aspects presented by Tamayo [12], and the project management book guide (PMBOK®) [13]. This methodologic process is composed by seven stages and it is presented in Figure 2. In addition, the methodology stages are summarized in the following subsections.

4.1 Identification of electrical characteristics

It consists on identify the most important characteristics of the installation such as physical distribution of the space (inside building), power capacity, voltage levels, location and topology of the substation (or substations), access points to the nodes (buses), number of circuits, the characteristics of the connected equipment (in each circuit) to the network and their levels of electromagnetic immunity.

At this stage, a visual inspection must be made to know the general state of the installations. This is also necessary to identify possible risk conditions such as high temperatures, instability of the structures associated with the electrical system, areas with high humidity or flood, points for public access that may generate electrical risk and signaling problems.

4.2 Variables to analyze

At this stage, the variables required for the PQ study must be selected. The number of variables to be analyzed depend on the particular needs in the PQ study. The basic parameters included in the PQ study are frequency, voltage, current, power, power factor and harmonic components. However, it is possible to include other type of analysis including the measurements of voltage sags, swells, flickers or transients.

During this process, the selection of the variables to be measured and the expected magnitudes for each electrical parameters define the characteristics of the required measuring equipment.

4.3 Network identification

In this step, the single-line diagram of the installation is used to identify the distribution of loads and the location of the elements that composes the internal electrical network, in especial, the areas of surgery and intensive care. These elements are power supplies, circuits, protections, insulation transformers, UPS devices, grounding and back-up systems.

In all cases, the technical characteristics of each element and each circuit must be included. These characteristics include power, voltage, current, current capacity, protection levels and electromagnetic immunity levels. The restrictions of the installation are also determined, and then, possible points for the measuring equipment connection must be identified.

4.4 Measurement and data recording

It implies the selection of the measuring equipment and the identification of places where the measure of electrical parameters could be conducted. For the selection of these equipments, the scope of the PQ study, the magnitude of signals, the order of harmonic components, the type of connections and the configuration of the network, must be taken into account. From these aspects, characteristics of the recording equipment such as resolution, precision, measuring ranges, monitoring period, sampling rate and storage capability are defined.

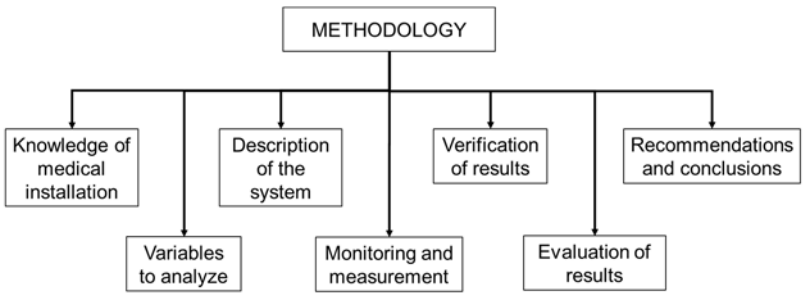

Figure 2. Methodology proposed for conducting PQ studies in health care institutions
Source: Adapted from NTC 2050

On the other hand, the selection of measurement points is one of the most important aspects in the PQ study, because their correct location determines the quality of data and the obtained results. In this stage, it is necessary establishing a main reference point that allows identifying if the disturbances are generated inside or outside the installation. To make the right decision, the measurement points are selected by evaluation of aspects

such as the availability of distribution boards (or panel boards), the access to the measurement points, the possible location of the measuring equipment, the safety conditions for personnel (experts in electricity) and equipments, the loads connected to the circuits, the demanded power and voltage levels.

In addition, a protocol to conduct an adequate monitoring process must be required. This procedure is composed by a sequence of instructions with the aim to identify the points of the installation where the major levels of disturbances are presented. The protocol must comply with the standard IEEE 1159, and require choosing an initial group of measurement points taking in to account the historical fault reports, the reports of previous measurements and the single-line diagram of the network [2], [14]. It is important during this process identify and include the critical points of the electrical system. Later, it is necessary carried out a previous set of measurements in several points. Analyzing these results, the next step is confirm or change the measuring points selected in the first part of the protocol. Figure 3 summarizes the sequence proposed for the measurement points identification.

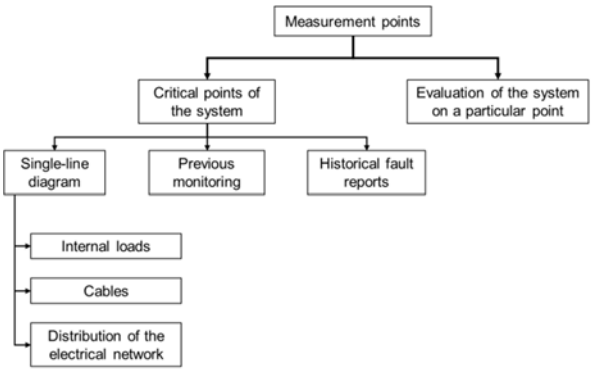

Figure 3. Process to choose the measurement points
Source: Authors

4.5 Results verification

Once the information is recorded in the measuring equipment, it requires a verification that results correspond to the selected electrical parameters and that the sampling time and the measuring period have been correctly selected. This is important because it must be verified that the stored information complies with the standard IEEE 1159 and that the records correspond to the date of the study [2].

4.6 Results evaluation

In this stage, it is necesary to perfom an evaluation of the results based on regulatory standards. The standards that must be included are IEEE 1159, IEEE 519, ANSI/IEEE 602, ANSI/IEEE 1346, IEC 60601-1, IEC 61000 and NTC 2050. During the analysis of results a classification of the type of disturbances recorded should be made, indicating whether the values found are within or outside the ranges allowed by the standards. Likewise, the sources that generate the disturbances must be identified and if these are outside the allowed ranges. On the other hand, it is necessary to identify the load conditions of the transformers and UPS devices, analyzing if they are sources of disturbances.

Subsequently, it is required to make a comparison between the values obtained from measurements and the levels of susceptibility and electromagnetic immunity of medical equipment using the IEC 61000-1-1 [15] and IEC 60601-1 [16]. This comparisson allows to know if the medical equipment are under risk condition. This evaluation is performed for each of the electrical variables examined during the study since the immunity levels of the equipment can vary between brands and manufacturers.

4.7 Reporting of conclusions and recommendations

Finally, the findings related with the type and level of disturbance are presented. The results must be presented for each PQ parameter analyzed. The risk analysis and the consequence of the disturbances for the electrical facilities and the connected equipment are also included in the final report. In addition, the possible disturbances sources are determined indicating which of them are internal or external to the network. Finally, the possible solutions for the problems encountered and for the disturbances mitigation are presented.

5. CONCLUSIONS

In this paper, a methodology for PQ studies in hospital and health care institutions was presented and summarized. This method provides allows to conduct a better tracking of the necessary activities to develop PQ measurements and the analysis of the medical equipment performance in this type of installations. In addition, the application of this methodology is useful in order to reduce the possible risk of the electrical facilities, circuits and equipments that can affect the life and safety of patients and medical personnel.

One of the most important advantages of the proposed methodology is that it integrates several technical standards (IEEE 1159, IEEE 519, IEEE 1346, IEC 61000, IEC 60601, NTC 2050 and NTC 5001) with the aim of comparing the requirements of the electrical network, the permitted limits for the disturbances that can be presented in care health installations and the limits of susceptibility and electromagnetic immunity of medical equipment.

Because it is a methodology applied to special installations, it is very important to analyze the risk presented at the moment of connecting the equipment in the installation. This is because, in reference to industrial facilities, in medical and hospital facilities there is a risk not only for the personnel conducting the study but also for patients and equipment.

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