Adapting the Neurology area of the Gustavo Fricke Hospital

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Abstract. Within the framework of the subject Clinical Engineering taught at Hospital Dr. Gustavo Fricke of Viña del Mar Chile, we were assigned to undertake a detailed study on the quality of the electrical power main supply of the Neurology Department, on account of reported malfunctioning of some equipment used in this unit. The study results indicated that the problems occurred only in a device for auditory evoked potentials device and, contrary to what was expected, the problem was unrelated to the quality of the electrical main supply. It was also found that the cause for the problem was electromagnetic interference (EMI) emitted from the system’s very own components. To solve the problem, we built a Faraday Cage for the signal-processing unit and increased the separating distance among the various system components. This approach enhanced system performance and significantly improved the recorded signals of patients. The solution adopted from this experience was suggested to others health care centers of our country that had been experiencing similar difficulties with the same type of medical equipment.

1. Introduction

Within the framework of the subject Clinical Engineering given at Hospital Dr. Gustavo Fricke of Viña del Mar Chile, we were assigned to make a detailed study about the quality of the electrical main supply at the Neurology Department, on account of reported malfunctioning of some equipments of this unit.

A hospital must be provided with a reliable and good quality electrical main supply, in order to ensure the quality of patient care. The general approach is to measure the various electrical parameters, meeting the Chilean standards, so as to establish the quality of the electrical main supply in a given clinical service.

Service quality of an electrical system can be quantified through several parameters associated to: i) service continuity; ii) voltage fluctuations; iii) harmonic content of voltage and current waveforms; iv) frequency variations [1]. In electrical systems of hospitals, harmonics measurement are the most relevant cause at the time of issuing a judgment on service quality, because they can affect the reliable operation of medical equipment. From this viewpoint, the Total Harmonic Distortion (%THD) gives a percentage value of distortion level that affects the correct performance of equipment [2].

The Neurology unit at Dr. Gustavo Fricke Hospital, as in other large hospital units, demands for an excellent electrical main supply for reliable service, on account of the special characteristics its medical equipment. Representative examples of these features are the low-voltage range of signals worked through this equipment, along with a low level of current consumption. For this reason, it is essential to know the present state of power mains by performing reliable electrical measurements. The interpretation of results must consider the special operative characteristics of this unit.
Performance problems in medical equipments directly affect the service quality the Neurology unit renders to its patients; e.g., they generate complications to diagnose pathologies, and, consequently, administrative problems arising from schedule changes in examination appointments. All this finally translates into economic loses for the unit, which –when going back to the source problem- makes the performance quality of the electric supply system a key factor for preventing such annoying problems.

In the present report we show the results obtained from measurements on the quality of the electric main supply at the Neurology service of Dr. Gustavo Fricke Hospital, made with by last-generation equipment. Finally, an analysis of results is included.

2. Overview of the problem

The Dr. Gustavo Fricke Hospital has a very old electrical installation (over 60-year old), with no reliable documentation available at present.

The Neurology service of the Fricke hospital is dedicated to perform registering of electrical brain and muscle activity of patients; e.g., studies of electroencephalography (EEG) and electromyography (EMG). In addition, they make tests on auditory evoked potentials with GSI equipment (model Audera); and traditional records of evoked potential (ABR, ECochG, AMLR and CAEP) and auditory steady state response testing (ASSR) [3].

The EEG studies are done with an analogical electroencephalograph Nihon Kohden and a digital electroencephalograph Cadwell purchased just a year ago, because of high-demand for said examinations. Both equipments work simultaneously in the Neurology unit and they can be taken to other units of greater complexity of the hospital, such as, the adults ICU, pediatric ICU and neonatology ICU, following the restriction of not to be connected in other hospital areas presenting deficient power supply quality:

Since the incorporation of the electroencephalograph and the digital auditory evoked potentials equipment in 2005, their operation was rather faulty by the electrical noise when recording brain signals. This condition made very difficult to attain a good assessment of patients, and caused test repetitions and delays which –finally- affected the patients and the diagnoses made by the specialist. Therefore, clinical complications occurred, like tests with wrong results or lacking a diagnostic value, all of which potentially leading medical misinterpretation. Repeated tests, rescheduling of patients appointments implied associated financial consequences to the hospital. Rescheduling appointments also has a very serious social component, by directly affecting patients who must repeatedly visit the unit to obtain a reliable assessment and/or to ask for another appointment.

It was observed, however, that the digital electroencephalograph works correctly in new areas of the hospital or areas featuring a good electrical installation. This allowed us infer that the source for equipment problems was the quality of the electrical main supply of the Neurology department; a very old installation derived from the main power distribution switchboard of the hospital. Therefore, the entire electrical installation for the Neurology department was overhauled by the hospital personnel.

The supervisor of the Medical Equipment Unit was in charge of overhauling the installation for the Neurology service. From utility network mains, three independent phases feed power to the new neurology electrical switchboard, with derivations to different electrical areas and uses of the unity. In order to improve furthermore the system’s operation, the team labeled the power outlets according to use, e.g., computing equipment (PCs and the like); heating (two electrical stoves); and examinations (two electroencephalographs and evoked-potentials equipment) (see figure 1). The new electrical installation did improve the performance of both electroencephalographs, but the problems with the auditory evoked potentials equipment persisted.

During the installation process of the new electrical main supply, only harmonics voltage measurements were made, because the hospital does not count with proper testing equipment. Hence, it was necessary to do new harmonic measurements, to detect possible harmonics from power mains, thinking it was cause of problems in the neurology equipments

16th Argentine Bioengineering Congress and the 5th Conference of Clinical Engineering
Journal of Physics: Conference Series 90 (2007) 012036
doi:10.1088/1742-6596/90/1/012036
At this point, it is worth mentioning that the Health Ministry of Chile (MINSAL), a few years ago implemented the Plan Auge (Acceso Universal con Garantías Explicitas), a new health policy that has allowed for incorporating new technology in public hospitals aimed at giving care and treatment to public in at least 57 diseases covered by this new health plan as of 2007.

Benefiting from this plan, the Neurology unit purchased two new medical equipments; one such unit was the auditory evoked potentials equipment. Equal equipment was also incorporated to several other public hospitals throughout the country.

3. Finding the solution

As stated before, to detect this kind of problems and others, a detailed study of the electrical main of the Neurology unit was made. To carry on the study, an electrical mains analyzer Circutor AR5 was used, which can measure different electrical parameters (harmonics, %THD, flicker, frequency variations, etc). For our case, however, the most important one is the harmonics study.

Harmonics are currents or voltages whose frequencies are whole-number multiples of the main frequency. Harmonics are originated by nonlinear loads that take current in sharp impulses, instead of doing it with a smoothly sinusoidal form, as it occurs with a purely resistive charge. These impulses create distorted current waves, as well as harmonic currents returning to other parts of the electrical distribution system [4].

A proper harmonics test had to be done at various points in the installation, from the incoming mains to the outlets for equipment plugs. In this case, the measurements were first made at the hospital electrical substation, i.e. the substation fed from utility mains, from which distribution branches feed all hospital areas; then, the test proceeded into the Neurology area.

3.1. Harmonics measurement at the substation level

Table I shows the study results from the substation’s main switchboard.

| Armónico | Tensión | Corriente |
|----------|---------|-----------|
|          | Amplitud | Desfase | Amplitud | Desfase |
|          | %       | [°]     | %       | [°]     |
| 3        | 0.643   | 111.2  | 4.460   | 285.1  |
| 5        | 1.881   | 149.7  | 3.741   | 69.5   |
| 7        | 1.627   | 332.5  | 2.787   | 216.6  |
The recorded values emphasize the amplitude and phase of voltage and current harmonics; the study is made on uneven harmonics because only these one caused problems. The total harmonic distortion (%THD) was 2.6 % for voltage harmonics and 6.8 % for current harmonics. It can be noted that the %THD value for voltage and current is smaller than 5 % and 9 %, respectively. These readings correspond to the allowed maximum as stated the electrical security Chilean standard NCH4/2003 [5].

Since no harmonics problems were detected at the electrical substation, measurements proceeded into the Neurology area so as to discard definitively any harmonics-related problem.

3.2. Harmonics measurement at the Neurology service

| Armónico | Amplitud | Desfase | Amplitud | Desfase |
|----------|----------|---------|----------|---------|
|          | %        | [º]     | %        | [º]     |
| 3        | 0.643    | 111.2   | 4.460    | 285.1   |
| 5        | 1.881    | 149.7   | 3.741    | 69.5    |
| 7        | 1.627    | 332.5   | 2.787    | 216.6   |

Table II shows the results from test on phase 1, assigned to neurology medical equipment, and highlight the value for amplitude and phase of voltage and current harmonics.

The value %THD obtained was 33 % for voltage harmonics and 55.9 % for current harmonics. It can be noted that voltage harmonics fall within the range permitted by Chilean standards. Although these harmonics present in the power phase feeding the neurology equipment can cause problems, an important factor is the current associated to them, that gives readings of only of 314 [mA]. These may pass by unnoticed, because these harmonics do not pose any significant effects on the electrical substation, which operates with current ratings well over 370A. To picture this difference, this harmonic current means fewer than 0.1 % of the substation values. From the above depicted readings, it can undoubtedly be concluded that the quality of electric power of the main supply in the Neurology Department is adequate for operative purposes. However, it is necessary to notice that the equipment of this unit works with very small biopotentials, which lie in the range of the micro volts. Therefore, the harmonics, linked to very small currents, could affect the equipment used in this unit.

| Armónico | Tensión | Corriente |
|----------|---------|-----------|
|          | Amplitud | Desfase | Amplitud | Desfase |
|          | %        | [º]     | %        | [º]     |
| 3        | 1.936    | 81.3    | 238.8    | 10.4    |
| 5        | 2.098    | 147.3   | 238.4    | 14.6    |
| 7        | 1.564    | 337.5   | 131.1    | 33.9    |
The Table III shows the amplitude and phase of the voltage and current harmonics presents in the board phase 3. The voltage %THD is 3.4 %, and the current was 96.5 %. It is important to mention that to this phase are connected the unit’s computing equipments. The high rate of current %THD due to the computer’s switching power supply, they are very good are harmonic generators.

Phase two was not considered or measured, because no medical equipment is connected to this phase.

3.3. Possible causes of the problem
With the results obtained by measuring the quality of the electrical main supply, it can certainly stated that the problems occurring in the auditory evoked potentials equipment are not caused by the presence of harmonics in the electrical mains.

Having discarded the above possible source, we started looking for other causes for the problem, suspecting firstly on electromagnetic interference, coming from the fluorescent lighting fixtures of the medical unit, or those originated at the system’s own computer, a notebook-like device with a switching power supply.

4. Results
In spite of having electric mains of good quality, the auditory evoked potentials equipment always worked deficiently. Considering this, we inferred as possible causes the occurrence of electromagnetic interference (EMI) that affects equipment operation, altogether with current harmonics stemming from the switching source of the equipment’s laptop. On these accounts, the possible solutions were: i) to implement a Faraday Cage to isolate the equipment against electromagnetic contamination; ii) to locate the computer at a greater distance from the equipment via a much longer USB connector cable between the equipment and laptop.

The implementation of a Faraday Cage is shown in figure 2 enveloping the signal-processing equipment for auditory evoked potentials. The Faraday cage is a conductive surface around the empty space that houses the processor, which acts as a shield against the external electromagnetic fields from environment sources [6].

![Figure 2. Electromagnetic isolation of GSI Audera equipment.](image)

After implementing the possible solving approaches and watching the equipment operate more reliably, the proposed solutions were considered affective. Namely, the implementation of a Faraday Cage, to locate the computer to greater distance of the equipment by means of a longer USB connector cable between the equipment and laptop, and to connect the equipment of evoked potentials and associated laptop plugged to different-phase sockets with the purpose of avoiding the overtones of current produced by the switching source of the laptop. With this combined solution, it was finally possible to reach at a significant improvement in signal registering of patients.

The solution adopted in this experience was suggested to other health centers of the country, which showed similar difficulties in the operation of the equipment of evoked potentials purchased through the AUGE plan.
5. Conclusions

After the analysis of results obtained from electric measurements of power supply quality of electric mains, we can confirm that the new electric mains system of the Neurology service is reliable for proper operation of the unit’s equipment. Hence, any anomaly in equipment performance will have to be traced to other factors. Under this reasoning, the faults found with the equipment of auditory evoked potentials GSI Audera had to be blamed to the electromagnetic noise interfering the signals captured by the equipment. To overcome this, a Faraday Cage was implemented and the laptop of the evoked potentials equipment was set at a farther distance. These actions allowed to totally eliminate the noise, thus obtaining a significant improvement in the quality of test made with this equipment. Problems when making were only detected examinations to 0 decibels. The previous thing it is come off that indeed there is presence of electromagnetic noise in the unit able to interfere with the signals caught by the equipment and the filtering of the overtones generated by the switching source of laptop is not sufficient.

The successful outcome of this approach permitted us to transfer it to other health centers in Chile that experienced similar problems.

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