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Study of Power Quality: Problems in Commercial Buildings in Puerto Rico

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***Abstract*--** **This paper describe studies of power quality done in Puerto Rico. A literature review will be done about different studies made in the past related to power quality problems in P.R. Data, from Lord Electric will be used to analyze some cases worked by this company in industrial buildings in Puerto Rico. Similarities and differences between existing problems will also be identified. To complete the objective, the software MATLAB was used where a program was developed to give the calculations of indices like THD, TIF, DIN, C-Message, and other indices, and also the spectrum of the signal sampling using Fourier analysis. Also, the use of digital filters is required for the elimination of noise and inter-harmonics to determine the indices and compare with the original results.**

The problem where was studied in Case 1 was that the Main Breaker was tripping for unknown reasons. In case 2 data transferring communication to U.S. was lost every Sunday in Home Depot at Bayamón, P.R. For the third case, hot spots, failed torque and methods are presented in Citibank Center at Cupey, P.R. to save money. Finally, this paper has a lot importance, because the problems of power quality as technology progresses will be more common in Puerto Rico and other places. This study will help to document answers about different problems of power quality in Puerto Rico and at the same time problems that could be common in other companies across the United States and the rest of the world.

***Index Terms*—** **Buildings, Grounding, Conductors.**

I. Introduction

PUERTO Rico, after 1950, experienced an economic revolution passing from agriculture country to a country where the industrialization to high technology is one of the most important parts of the national economy. Generally, for high technology industry the highest conditions of security and quality are required to develop products. For example, the cost to produce a kilogram of a medicine commercially is $200,000. Any problems in production can cause millions of dollars in losses. Problems like voltage sags, or other variations in the voltage, can produce losses of many millions of dollars. If the problems aren't fixed on time.

For this power quality study are presented three cases in Puerto Rico, two of them in the Home Depot Area at Bayamón, P.R. The other case of study will be an infrared study in the Citibank at Cupey, P.R. For the first two cases the initial conditions, the harmonics, the events, the Voltage, Current and Frequency, (VIF), and the power are presented with their graphics and data. Also the paper will present the infrared method and examples of how the hot points can affect a power system.

Before Power Quality is defined, it must be understand that there are different definitions from the point of view of utility and the customer. First, the utility definition is the quality of electric service necessary to provide reliable electric energy to the user at a satisfactory level so as not to disturb, harm, or affect the performance of electrical loads. But the customer definition is hassle-free power [1], [2].

The problems in Power Quality appeared for first time in the beginning of the 80's with the introduction of nonlinear loads like computers, power electronics, internet, etc [3], [4]. The principal Power Quality areas are transitory type interactions like electrical noise, lighting, switching surges, swell/sag/surge conditions and non-transitory type interactions like harmonics. To measure these types of problems, the CBEMA Curve. This curve was designed in the 80's from Computer & Business Equipment Manufacturers Association (CBEMA) to measure effects of the events of voltage in computers and at the same time is used as a data logger, a meter to register the different events caused by the electrical disturbances.

Those electrical disturbances could be caused by the normal utility service like circuit breaker operations and automatic closers creating momentary switching problems and outages [3]. Devices like computer components can cause electrical disturbances, which produce high frequency noise and changes in the fundamental waveforms. This noise is known as distortion [5]. Other electrical disturbances are lightning strikes, motor starting & stopping, trees, welding, copy or printing machines, etc [4].

II. Case of Study 1 - Home Depot Main Breaker

A. Date of study: October 1, 1999 until October 4, 1999

Problem: The Home Depot of Bayamón, Main Breaker (Cat. No. CRD316T36W) 1600A 480/277V, at the 38KV Substation was tripping for unknown reasons.

Place of the Power Quality Analysis: 38KV Substation Main Breaker.

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Instruments to perform the analysis: Power Meter, to record any event.

Preliminary recommendations: Power Quality Analysis on the 38KV Substation Main Breaker Operational test on the Cutler Hammer equipment model STK2.

Preliminary results: Possibility of high inrush current when power is re-established. Inrush current (Flicker Effect) may exceed current rating of the Main Breaker Fig. 3.

Final results: The time of delay on the breakers was changed. Originally, the Delay Setting was set at 2 s and the Short Delay Time was set on 1 s. Now, the Delay Setting is 4 s and for the Short Time Delay is 0.3 s. This is a temporary solution to solve the inrush current problem.

B. Discussion and analysis for Case 1

The problems with the inrush current occurred because the use of electric loads drastically increased creating overshoot for short time. The spike was faster than the operation of the breaker; hence, the substation breaker tends to trip. But this type of spike does not represent any danger to the system. Using Fourier analysis of the voltage phase A, the current phase A, and the ground currents, the analysis reflects that there are a lot of harmonics, due to noise created for the loads Fig 1-Fig 3. These harmonics are the result of the interaction of the environment noise and magnetic nonlinear loads. For this system, the production of harmonics could also be due to the size of the neutral line.

The event with the inrush current was directly related with the tripping of the breakers. This event occurred when the Air Conditioner was starting. If the inrush current of the HVAC is more than the current rating of the breakers, the result is that the breakers will trip.

The creation of this inrush current is because the HVAC consumes approximately a quarter of the total real power [6]-[8]. When the HVAC is quickly turned off or turn on, the quantity of electrons in a small segment of the wire will change from a small quantity of electrons to a huge quantity of electrons or vice-versa producing inrush current [5].

The noise produced could be produced by interactions of telephone lines with power lines. The effects of the interactions of the harmonics and the inrush current are shown in Fig. 4 for Phase C. It shows a voltage interruption created by the inrush current when the Main Breaker trips. A voltage interruption will affect the power factor creating distortion. The distortion creates power losses leading to additional money that companies need to pay to the Electric Service Utility.

Permanent implemented solutions for these types of problems are Shielded Isolation Transformers with K-factor protection; the SIT's are very useful for a 60Hz and high frequency grounding system bonded together, or, if the electric loads are very sensitive, it should be connect an IG Receptacle to reject the noise to the loads. Another solution is to resize the neutral conductor reducing the current density [7], [9].

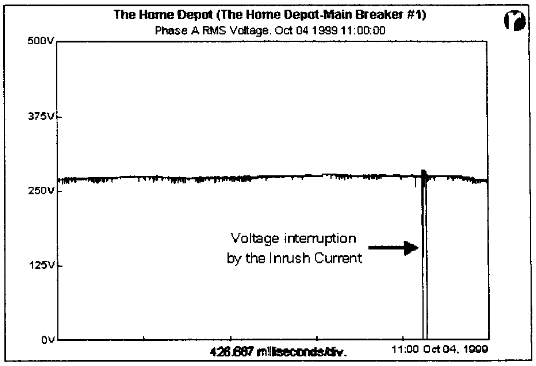

Fig. 1. Voltage Phase A Spikes

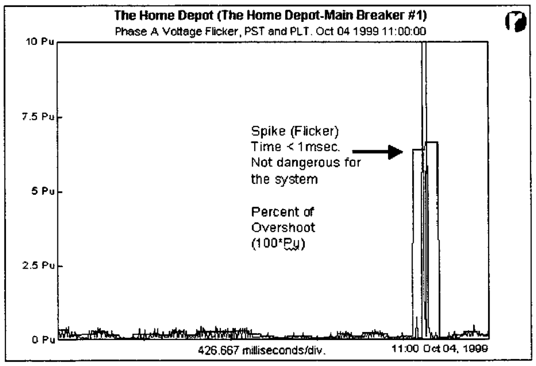

Fig. 2. Phase A Percent of Overshoot (100*Pu)

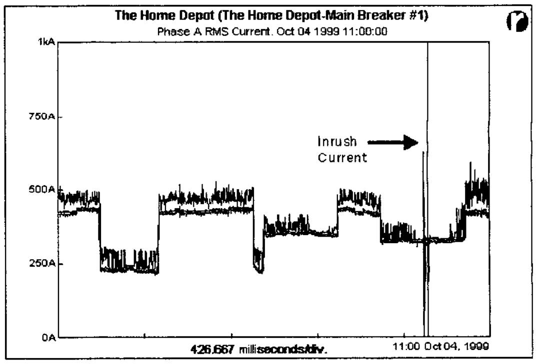

Fig. 3. Phase A Inrush Current

III. CASE 2 - UPS IN THE COMPUTER ROOM

A. Date of study: February 6, 2000 starting at 10:30 PM until February 7, 2000

Problem: The Home Depot of Bayamón was losing the data transferring communication to U.S. every Sunday between 12:00 AM and 2:00 AM.

Place of the Power Quality Analysis:
The electric circuits for the UPS and the EMS system

Instruments to perform the analysis:
Power Meter, to record any event

Preliminary recommendations: Direct study on the UPS and telephone lines. Also, the implementation of a Signal Reference Grid (SRG) can be considered for the ground terminal. A SRG is a mesh of all the grounds in one terminal.

Preliminary results: Using a tracer for the electric circuits for the UPS, it was found that the Branch Circuit Panel that supplies power to the UPS was not connected to the EMS system. On January 16, 2000 starting at 11:00 PM a small outage was observed but the UPS continued working normally. The UPS was on bypass mode. The solution was to change the position of switch from bypass mode to UPS mode to serve the loads.

Final results: Used a Power Meter on the Branch Circuit Panel that supplies power to the UPS to record the different events. At 12:45 AM, the emergency generator started to run because the emergency generator was on exercise mode with duration of 30 minutes every Sunday at that time. Originally, the UPS was on bypass, which it did not offer any protection to the computers and when the Automatic Transfer Switch (ATS) performed the transfer to the emergency generator, it had created a problem with the change of voltage on the computers every Sunday. A loose neutral was found which it could cause possible voltage spikes and inefficiencies. Also these systems must have a dedicated ground line to avoid voltage spikes by other connected loads. After the implantation of the solutions, the system worked without problems.

B. Discussion and analysis for Case 2

Fig. 5 shows the Voltages A, B, C and Neutral in the UPS in the Computer Room. The Neutral Voltage is zero for a symmetric balanced three-phase system [6], but in Fig. 5, it is shown that the Neutral Voltage has oscillations resulting in an unbalanced system and the harmonics injection in the ground current and losing the data transferred. If the ground current is not zero, the power losses are created in the form of harmonics. The Fourier analysis is shown in Fig. 6. The harmonics will interrupt the data transferring communication.

The voltage in the neutral, which it is very typical in commercial buildings where there are computers, Internet, telephone lines and other elements interacting between them creating noise, it looks with oscillations. These oscillations are created by the mutual inductance and resonance between the UPS, telephone lines and the computers. Finally with the use of the CBEMA Curve, Fig. 7 presents the events that affect the transfer data can be identified, in this case when the emergency generator

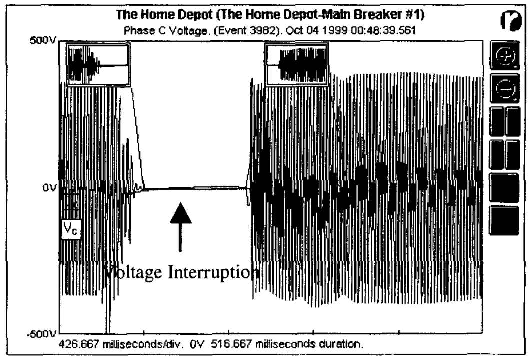

Fig. 4. Voltage Phase C after Inrush Current

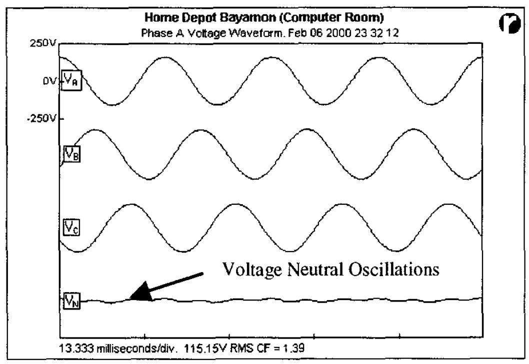

Fig. 5. Voltages in the UPS on Computer Room

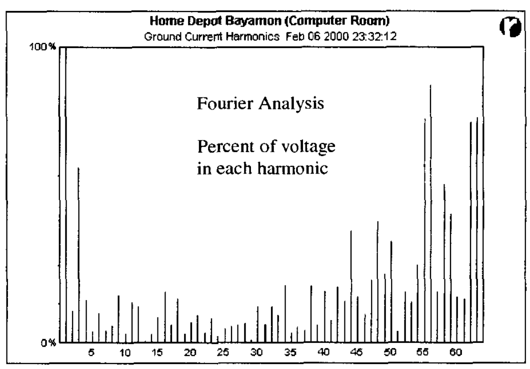

Fig. 6. Ground Current Harmonics in the UPS

runs on exercise mode. The stable region represents the maximum and minimum tolerance for the voltage allowed after turn on power across the time. The unstable events represent when the emergency generator starts to run on exercise mode. Each event is a voltage drop or increase of the nominal voltage. For the solution to resize neutral, it needs to be 1.73 times the phase conductor ampacity in a 208/120V shared neutral system [9].

IV. Case 3 - Electrical System Analysis for Citibank Center

A. Date of study: February 2, 1999

Problem: Failed torque in the breaker panel, hot spots, and method to save money.

Place for the Infrared Study: Breaker Panel

Instruments to perform the analysis: Infrared Thermograph Camera.

Preliminary recommendations: Infrared inspection and Thermographic Imaging Analysis

Preliminary results for different panels: Many of the breakers in the panels were with hot spots. Many breaker lugs were hot. Creating a voltage drop of more than 100 mV. Breaker terminals were hot. Connections on the on the transformer bushing was hot. Improper torqued connections. Arcs produced between knots, see Fig. 8. Some Fins were not operating correctly. Neutral was hot.

Final results: Replaced the hot breakers, cleaned connections of the transformer bushing and retorqued. The breaker lugs were hot because the circuit was working near full load. One recommendation was to create specialized panel for a better redistribution of the loads. Shutdown was required. Performed a preventive de-energize maintenance.

B. Discussion and Analysis for Case 3

The Citibank Center is one of the more important buildings for the Citibank Corporation in Puerto Rico. The main reasons are that it is the headquarters of Citibank Puerto Rico and it is where all the information is received and transmitted to the rest of the world. The last study in Citibank was performed without shutdown, in other words the study was performed when the Citibank was in full operation without affecting any work for the day.

A lot of problems were identified using Thermographic Imaging Analysis. Problems found were hot spots in the breakers, hot terminals, hot transformer bushing, neutral hot, a voltage drop more than 100 mV, etc. A Thermographic Imaging Analysis for the Neutral Conductor is shown in the Fig. 9.The thermal problems are produced by the electric arc thermal energy between the knots. The solutions in some cases were simple like

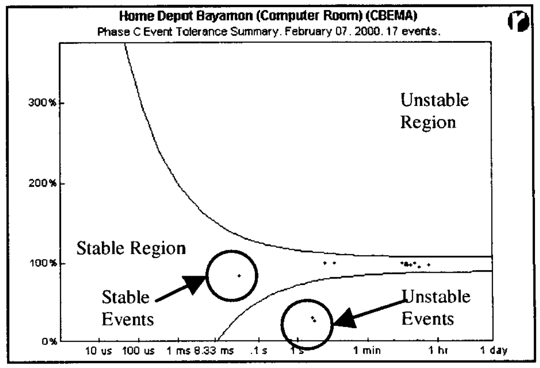

Fig. 7. CBEMA Curve

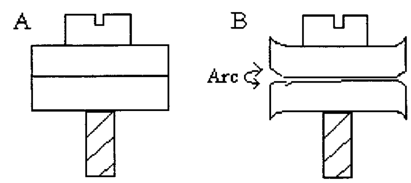

Fig. 8. Properly torqued connection A vs. poor torqued connection B, between the knots

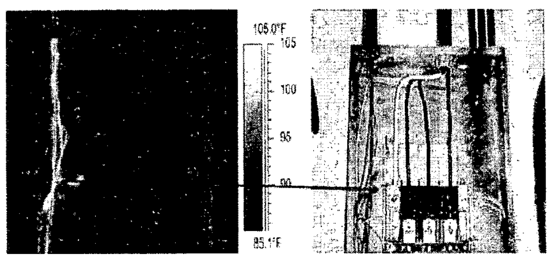

Fig. 9. Infrared Inspection for the Neutral Conductor

changing the breaker, but in other cases the solution was maintenance and retorquing. In other cases the solution was to resize the conductors like the neutral, or to perform a preventive de-energized maintenance.

The importance to eliminate the hot spots is to reduce the risk to create severe problems in the loads. With the infrared testing, loose connections, current overload, and defective insulators that cause safety hazards and outages when the building is in operations were detected.

But how a simple retorque of the connections save money? In the case of Citibank, the following data was obtained for one electric switchboard and the screws with their additional power consumption.

Proper Torqued Characteristics
Proper Torqued Resistance = .06 Ohm
2400 Watts per Hour Resistance ($W=I^2R$)
Poor Torqued Characteristics
Incorrect Torqued Resistance = .16 Ohm

6400 Watts per Hour Resistance ($W=I^2R$)

The Bus Bar was under a 200 amp constant load, hence the difference in Watts between proper and incorrect torque was 4000 Watts. Taking that the average price per Kilowatt-Hour in Puerto Rico is \$0.035 for commercial buildings; the cost of energy wasted was \$1,226 per year for only one connection.

In this electric switchboard, they had around eight improper torque connections. A simple retorque of the connections saved a lot of money to the Citibank. Also, the study was doing when the bank was in normal operations.

V. Conclusions

Three different cases of study about Power Quality in Commercial Buildings have been shown. In some cases, problems appear like waveshape, flicker effect, triplens, voltage sags and outages. All of these problems were found in commercial buildings in Puerto Rico. The most interesting is that some problems where common in the three cases like poor wiring connections or energy waste. The solutions were dependent on the problem. In some cases the solution was replace the breaker or change the time delay in the Automatic Transfer Switch but in other cases the solution was more expensive like preventive de-energize maintenance or a resize of the wires.

This report proves that in Puerto Rico, many companies are interested in the topic of power quality because they can save a lot of money and prevent future problems to the loads. Also, this report shows that in Puerto Rico, we are working with the problems of power quality and finding solutions for the different problems. At the same time these power quality problems are typical problems that they can occur not only in Puerto Rico. These problems can occur in any commercial building around the world taking in consideration the changes in the technology and the increment of nonlinear loads like computers, fluorescent lights, internet, etc. It is expected that this paper will be used as a future reference in the area of Power Quality for commercial buildings.

VI. Acknowledgment

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VIII. Biography

Eduardo I. Ortiz-Rivera was born in Barranquitas, Puerto Rico in May 30, 1977. He received the BSEE degree (Magna Cum Laude) from the University of Puerto Rico-Mayagüez in 2000 and the MSEE from Michigan State University in 2002. Currently, he is a Ph. D. candidate in Electrical Engineering in the area of power electronics at MSU. His research interests include power electronics for utility applications, electric motors, distributed power generation, robotics and mathematical modeling for dynamic systems.

Mr. Ortiz-Rivera has received the national GEM Doctoral Fellowship, Alfred Sloan Fellowship, Competitive Doctoral Engineering Fellowship and he is a Future Faculty Member of the University of Puerto Rico, Mayagüez Campus. He has worked for Fermi National Accelerator Laboratory in the Physical Particles Division and LORD Electric Co. in the Transmission Lines Division.

Mr. Ortiz-Rivera is a registered Engineer In Training in Puerto Rico, member IEEE Power Systems Society, Society of Hispanic Professional Engineers, Tau Beta Pi and Golden Key International Honor Society.