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Photovoltaic Energy to Face an Earthquake

Andrés Emilio Delgado González [a], W. Manuel Saltos Arauz [b], María Rodríguez Gámez [c], Lenin Agustín Cuenca Alava [d]

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Correspondence Author [a]

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Abstract

The application of photovoltaic technology is necessary to reduce the harmful effects of an intense earthquake in the city of Portoviejo. It is based on the information obtained about the occurrence of the earthquake on April 16 and considering data from other events of the same nature occurred in the territory, an assessment of the seismic risk for the city and by characterization of one of the zones is made subject to danger, the introduction of photovoltaic luminaires is proposed in order to provide certain strengths that can facilitate the work of the first urgency in the rescue and urgent repair of breakdowns, as well as the evacuation of the population to safer areas especially at night. An analysis is made of the technological structure of photovoltaic luminaires and the prices they have in the market, both internally and internationally.

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[a] Graduated from the Engineering in Electricity. Universidad Técnica de Manabí, (Ecuador/South America)
[b] Aspiring Doctor of Technical Sciences, Electrical Engineer, Universidad Técnica de Manabí
[c] Ph.D. Professor and researcher Universidad Técnica de Manabí
[d] Aspiring Doctor of Technical Sciences, Electrical Engineer, Universidad Técnica de Manabí

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1. Introduction

The planet is going through serious problems of environmental pollution, accompanied by catastrophes, such as earthquakes. The industrial revolution that took place in the second half of the 18th century caused an incredible demand for energy and involved the implementation of power plants, which mostly emitted polluting gases. Currently the case is not very different, the largest generation power plants in the world emit large amounts of C02 into the atmosphere, but unlike what happened in the past, renewable energy generation has taken hold, and despite being expensive in terms of their structural implementation, they do not represent pollution due to gas emissions. One of these renewable energies is photovoltaic, which uses the electromagnetic radiation emitted by the sun to generate electrical energy.

In Ecuador, for the provision of electricity, there is an interconnected national system that is supplied by the generation of hydroelectric plants, wind power plants and thermoelectric power plants that consume petroleum products and emit large amounts of CO2 into the atmosphere, in the same way the service is not insured due to the distribution conditions that make it very fragile due to the geographic irregularity that exists in the territory and that in case of natural disasters can collapse the system generating serious problems such as those that occurred on April 16th, so that it is necessary to have autonomous supplies such as the one that is being proposed in the project to provide energy in certain areas that are of special social interest.

At present, the emergence of new sources of renewable energy in the international energy landscape is evident. The construction and adequate use of the solar modules basically propitiate the preservation of natural resources, the saving of oil and the minimization of the environmental impact derived from the electric generation. Since the applications of photovoltaic technologies began at the beginning of the 20th century, their main application was carried out in the aerospace career and later it was used to guarantee the service in regions or isolated places of the electric network. Recently there has been a boom in photovoltaic applications connected to the network, mainly in Europe. But the photovoltaic technology can be useful in other applications where it is required to guarantee the service under abnormal conditions when the interconnected service is interrupted.[13,14]

The province of Manabí qualifies as one of the territories with the most seismic activity in Ecuador. Since August 5, 1949, a total of 7 intense earthquakes above seven degrees have been registered in the national territory. Three of them have had the epicenter in the province of Manabi province, including the earthquake on April 16 with 7.8 degrees of intensity. Previously, there had been one on May 19, 1964, or 8 degrees and on August 4, 1998, with an epicenter in Bahía de Caraquez, of 8 degrees of intensity. It can be said that on average between 15 and 20 years there is an intense earthquake in the territory of the province.[15,16]

The occurrence of an intense earthquake is capable of generating great destructions, even with significant changes in the landscape and the orography of the land, with the potential to cause a great material and human losses. The first hours and days after the natural phenomenon occurred, they are characterized by the destabilization of the established social order. People spend the night in parks, public roads, and open spaces. The tragedy increases with the sanitary danger due to the emergence of epidemics, the poor quality of the water and the interruption of the supply cycle of the precious liquid, which is joined by the lack of electricity, with the greatest complications and difficulties during the night, where the darkness can complicate the works of rescue, urgent repair of faults and the evacuation of the population.[17]

The city of Portoviejo, capital of the province of Manabí was founded on March 12, 1535, located on the banks of the river of the same name, which has allowed it to become a commercial city forever. At the moment its population arrives at the three hundred thousand inhabitants

considering itself like a pole of commercial and administrative development of the province since here they are settled the majority of administrative offices of the province and the central government.[1]

The city of Portoviejo does not have a lighting capacity with autonomous photovoltaic systems that could be a solution to the power interruptions that depend on the interconnected national system in case of the occurrence of a natural disaster, which would create conditions in the parks for shelter of the people in case of earthquake, the investigation was carried out in the park Eloy Alfaro Delgado, with the aim that this can become a solution that provides some level of security to the population because it is considered a wide and open area where they converge several main roads that serve to bring the population together.

The seismic potential of the province of Manabí implies that the territory is in permanent danger of the occurrence of an intense earthquake, with the potential to generate high-risk situations, where electric service plays an important role, mainly during the night hours.

The installation of autonomous photovoltaic technology has the ability to ensure the supply of electricity in complex situations when for obvious reasons the centralized system is interrupted, reason enough for the design and study approach of an autonomous photovoltaic lighting system can become a solution to ensure the reliability of the public lighting service.

The Eloy Alfaro Delgado park, located in front of the Cathedral of Portoviejo, is a space that due to its characteristics generates confidence of the population to come and protect themselves in the event of an earthquake. This aspect was corroborated on April 16, when immediately after the earthquake occurred hundreds of people came to the site seeking safety for the effects of destruction that turned the city into chaos.

An earthquake occurs instantaneously and simultaneously shakes a large area causing serious damage; this makes it considered one of the most destructive and feared natural phenomena. The consequences of people and their activity can be direct or indirect: Directly causes dead, injured, destruction of homes, public and industrial facilities, etc. Indirectly they cause landslides, fires, floods, tsunamis, epidemics, and the economic ruin of the affected region.[2]

It should be clear that the earthquake is a natural phenomenon capable of shaking the Earth 10,000 times more violently than the Hiroshima bomb, it is still largely unpredictable. More than 500,000 seismic movements take place every year.[3] The seismic factor is a characteristic of the Ecuadorian geology, therefore the best way to protect against this natural event is that the population and social infrastructure are prepared to reduce its effects.[4]

The Earth's crust is a vast puzzle of moving tectonic plates. The driving force of the plates originates in the depths of the Earth. When the plates collide with each other as they travel across the globe, the movement is felt on the surface. Seismic faults are the line where two plates meet.[3]

The most superficial part of the Earth is divided into a number of blocks or tiles that are called "Tectonic Plates". These blocks have a thickness ranging from approximately 15 to 50 km and make up what has been called the "Lithosphere", which is the rigid part of the "shell" of the Earth and includes both the crust and a part of the Mantle. The layer of the Earth that is immediately below the Lithosphere is the Atmosphere, which is not rigid. The tectonic plates move dragged by the supra lying material having speeds of the order of cm/year.[5]

The speeds and directions of movement between plates are different, which results in interactions at the borders of said plates. There are three main types of the boundary between plates:

1. Convergent. - In this type, the plates have had a "collision" and usually, it happens that one of them (the highest density) penetrates below the other.
2. Divergent. - In this type of border, the plates are separated in the opposite direction starting from the border, due to the emergence of material from the interior (Mantle). The frontier usually forms a type of ridge (dorsal) with a groove at the top and is most commonly located on the ocean floor.[5]

3. Elastic borders. - In this type of boundaries the plates move with lateral displacements, that is, they pass one next to the other, that is to say: the plates move in the opposite direction laterally, following the same course of the border that corresponds to the fault line main (this line is the intersection of the fault plane with the surface).[5]

Analogously, both in the subduction zone and in any other type of failure, the tension gradually accumulates until a limit is exceeded, at which point a fault begins to appear at some initial point called focus, from where said fault or rupture continues. to occupy a certain extension the entire length and width of a plane, called the plane of failure.[6]

One of the affectations that turns out to be typical after the occurrence of an earthquake of great intensity, is related to the interruption of the electrical service, which makes difficult the accomplishment of the works of rescue and urgent repair of faults from the first moments and later days to the occurrence of the earthquake, a situation that gets worse at night, when darkness is practically generalized and activities become more complex and dangerous.

In particular, solar energy is among the most widely used of renewable energies, which leads to a better use of the natural resource to produce electricity.[7]

On the other hand, the photovoltaic systems that are available to make effective use of solar energy and convert it into electricity, are divided into two large groups: autonomous systems without connection to the network and systems connected to the network.[8]

The autonomous systems without connection to the network consist of a system of solar capture (solar cells arranged in panels), the batteries to store the electricity generated in direct current and the control system to ensure the correct operation of loading and unloading the batteries.[19] These autonomous systems were initially used in the aerospace career, then to guarantee the supply of electricity in places where there is no conventional electricity network in rural areas, and recently they have been designed for public lighting.[8]

Among the most frequent current applications are the following:

a) Public lighting systems where high reliability of the lighting service is required in any condition of the situation
b) Radio repeaters, whether or seismic observation stations and transmission
c) Water pumping equipment
d) Road, port and airport signaling systems
e) Campsites and service areas for motorhomes
f) Advertising facilities
g) High altitude shelters

On the other hand photovoltaic solar energy has managed to open a new reality in the field of production that actively encourages the participation of all citizens in the protection of the environment, since the energy from the Sun, does not produce toxic waste or gases of greenhouse effect, as well as allows the democratic distribution of its economic benefits among the whole society.[9]

In Ecuador, the use of photovoltaic systems has a penetration and development still incipient. During the last 20-25 years, the technological development in the field of photovoltaics worldwide has allowed a reduction of 95% in the cost of commercial photovoltaic modules, at the same time an increase close to 200% in its efficiency.[9]

The solar luminaries that are on the market, constitute an unbeatable offer that can compete with any of the traditional technologies in the technical, economic, environmental and social. The operating system is based on the electrical generation by means of photovoltaic generators, to be stored in a bank of batteries and to use this energy during the night, when the specialized lamp is turned on automatically, which is regulated for its optimal functioning by an electronic card. Existing experiences of its massive application in countries of America like Mexico.[10] The objective of the research is to design an autonomous photovoltaic lighting system in the Eloy Alfaro Delgado park, to face natural disasters.[20]

The investigation will be developed in the surroundings of the Eloy Alfaro Delgado park, in front of the Cathedral of the Good Shepherd. Figure 1 shows the micro-location of the study area framed in red lines.

Figure 1. Area selected for the study

2. Research Method

Field research was carried out, defined as the process that, using the scientific method, allows to obtain new knowledge in the field of social reality or to study a situation to diagnose needs and problems in order to apply knowledge for practical purposes (applied research). This type of research is also known as on-site research since it is carried out on the site where the object of study is located. This allows more in-depth knowledge of the researcher, can handle data with more security and can be supported in exploratory, descriptive and experimental designs, creating a control situation in which it manipulates one or more dependent variables (effects). A measurement of the data will be made; in the proposed case, it will allow obtaining information regarding the design that seeks to generate a level of security in case the public lighting of the interconnected system will fail as a consequence of a natural disaster.

The selected method is Hypothetical-Deductive, by stating that you can analyze different elements and perform their experimental verification. It is necessary to remember that one of the characteristics of this method is the combination of other methods such as inductive, deductive and experimental. Detailed and explanatory tours of the so-called "Measurement Dynamics" were made, including all those who for some reason frequently attend the Eloy Alfaro Delgado Park and which will allow having a safe area in the event of a negative event such as a natural disaster. of serious consequences.

Surveys were applied to citizens who frequently go to the Eloy Alfaro park and the Cathedral, different bibliographies were made and some elements of the statistics were used to graph the results of the research.

3. Results and Analysis

The neighbors of the study area and people who visit the Eloy Alfaro park and the cathedral who lived the experiences of the earthquake on April 16, 2016, were surveyed.

A sample calculated by equation 1 was taken.

$$n = \frac{(Z)^2(P)(Q)(N)}{(Z)^2(P)(Q)+(N)(e)^2} \quad (1)$$

Where:
n→ Sample size
Z→ Confidence level
P→ Probability of occurrence = 0.5
Q→ Probability of non-occurrence = 0.5
e → Probability of error = 0,1
N→ Population or universe

We tabulated and quantified the results of 94 surveys of neighbors and people who visit Eloy Alfaro Park frequently and who lived the experiences of the earthquake on April 16, 2016. We inquired about the knowledge that people have about the high seismic risk of the earthquake. city of Portoviejo, the levels of seismicity of the territory and the role that photovoltaic luminaires can play to maintain the vitality of street lighting in the event of the occurrence of a natural disaster.

The graph of Figure 2 shows the criteria regarding the knowledge of the population about seismicity in the city of Portoviejo.

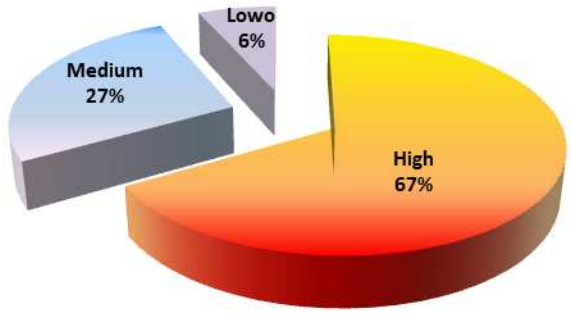

Figure 2. Percentage of knowledge about seismicity

When the results are valued, it is noted that the population of the province of Manabí qualifies as one of the Ecuadorian territories that has a higher seismic risk. The above is corroborated in the historical seismic of the country, because of the major earthquakes that have been recorded include: Riobamba (1797), Ibarra (1868), Ambato (1949) and Saturday, April 16, 2016, at 6 and 58 in the afternoon.[11]

People also know the levels of seismicity that can be expected, Figure 3 shows the percentage of people who dominate these concepts, as observed 59% of people dominate the levels of seismicity.

The occurrence of an intense earthquake can cause the collapse of buildings and structures endangering people's lives, interrupting traffic and hinder emergency first-aid activities and urgent repair of breakdowns, to this situation we must add that When darkness occurs at night, it hinders, even more, the activities that can be fulfilled. The earthquake that occurred on April 16, 2016, and that hit the province of Manabí with intensity caused a significant amount of damage and destruction with hundreds of losses in human lives and thousands of injured and injured, with a cost higher than three thousand millions of dollars.

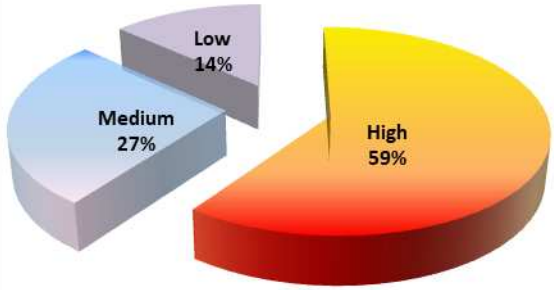

Figure 3. Percentage of people who dominate the levels of seismicity.

It was opportune to inquire about the probability of interrupting the electric service of the conventional network, where 67% of the people surveyed agreed that the first thing that collapses is the electric power service, as shown in figure 4, corroborating that they must create the conditions by locating systems that can continue to be enabled in the event of an earthquake.

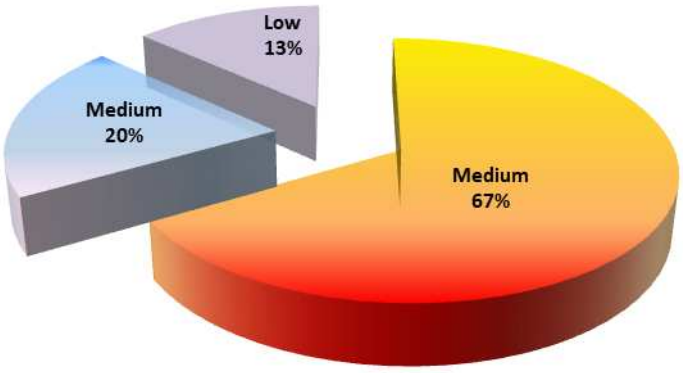

Figure 4. Knowledge of interruption of electrical service with an earthquake

With the occurrence of an earthquake, the traditional public lighting must be disconnected automatically for safety, but there are other alternatives that can guarantee the functional vitality of a given energy system and in this case, you can be talking about photovoltaic luminaires. The importance of the maintenance of public lighting derives from the very important that, at those times, emergency work can be in the rescue, urgent repair of faults and evacuation to safe places, especially when these activities are carried out at night.

In the difficult social conditions that are generated by the great destructions, collapses of buildings and the interruption of roads caused by an earthquake, it is very difficult for people to play a highly effective role in the provision of first aid and the realization of the work of the first urgency in the rescue and urgent repair of breakdowns at night hours when the public lighting service is interrupted, because the difficult situation created adds the disorientation of the people that become more intense when they cannot have a source reference of lighting. If at least the vitality of public lighting is guaranteed in the streets and avenues in high-risk areas, the actions to be developed from the first moments that are the most important to save lives could be facilitated

Photovoltaic luminaires

Photovoltaic luminaires can ensure public lighting service in any condition of the situation, even when the centralized electrical system collapses due to the occurrence of a natural disaster. These technologies belong to the group of autonomous systems, that is, they can work independently of the conventional centralized system, since the fuel they use is the Sun, with a virtual cost equal to zero, is the most distributed of renewable sources, with high availability throughout the territory of the province of Manabí.

Immediately after the occurrence of an earthquake, the maintenance of public lighting is very important, since it has been demonstrated that the greatest number of lives can be saved in the first hours after the accident occurred, and for safety reasons the vitality of the luminaries they can play an irreplaceable role. Photovoltaic luminaires offer the possibility of ensuring the vitality of public lighting at all times, even when the collapse of the centralized system occurs.

The fuel of photovoltaic technologies during the generation of electricity is the sun and therefore has a virtual cost equal to zero. The saving of oil is one of the great advantages offered by photovoltaic luminaires. The electrical energy consumed in the province of Manabí is of thermal origin,[12] based on the burning of oil. In the thermal power plants that exist in Ecuador to generate one MWh of electricity, an average of 0.25 tons of oil is consumed, this means that for every 4 MWh of photovoltaic energy that can be consumed by renewable luminaires, it is possible to save up to 1 ton of oil.

The contribution that photovoltaic luminaires can offer in terms of reducing CO2 emissions is another of the important advantages offered. in the burning of oil, which can generate about 0.9 tons of CO2 per MWh generated, this means that for every 1 MWh of photovoltaic energy that can be consumed by renewable luminaires, the emission of almost one ton of CO2 to the atmosphere.

Photovoltaic luminaires classify between autonomous photovoltaic systems, which have the technical capacity to maintain the reliability of the service in extreme situations, when any other generation technology could collapse, and from the normal situation can promote the saving of fossil fuels by concept of electricity generation, reduce losses and encourage the reduction of CO2 emissions into the atmosphere.

From the technical point of view, an autonomous photovoltaic system designed to function as a luminaire presents a very simple and inexpensive structure. Each system is integrated by a small generator that results in the photovoltaic module; a charge control system that functions as a battery protector; the deep-cycle photovoltaic battery; the luminaire that is preferably of the LED type and when said luminaires consume alternating current (AC), a DC-AC inverter can be added. These are technologies that are available in the energy market.

4. Conclusion

It was found that the conventional electrical system does not ensure the reliability of public lighting for disaster situations, because on April 16, 2016, at 6:58 pm with the occurrence of the intense earthquake of 7.8 magnitudes on the Richter scale, the electrical system was interrupted leaving the city of Portoviejo in the deepest darkness and under the destructive effects of the natural phenomenon. This situation takes place due to the danger of fire that represents the maintenance of the service in the event of an intense earthquake.

The province of Manabí has a high seismic risk, which implies the constant preparation of the infrastructures found in the sites classified as high risk, especially in the cities and their capital, within which is the public lighting to face the natural phenomenon in better conditions and favor the work of first urgency in the rescue and urgent repair of breakdowns, as well as the evacuation of the population to safer places

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Biography of Authors

	Graduated from the Engineering in Electricity of the Universidad Técnica de Manabí, Portoviejo. Ecuador
	Aspiring Doctor of Technical Sciences, Electrical Engineer, Has worked in various research primarily directed to the use of microgrids with renewable energy sources, it has participated in scientific events as the author of several currently working on the issue of the use of renewable sources in form of distributed generation through microgrids that enhance power quality and decrease environmental impacts.
	Ph.D. Strategies and Planning territory Renewable Energy Sources, Universidad Pablo de Olavide, Sevilla, España, PhD. In Geography. Associate Professor and researcher at the Universidad Técnica de Manabí. It has participated in various international research projects aimed at rural areas using renewable energy sources currently working on studies using GIS to study renewable potential and use in distributed generation
	Graduate of Electrical Engineering at the Universidad Técnica de Manabí (UTM), Portoviejo, Ecuador. Master in Educational Management. Assistant Department of Electrical and coordinator of the School of Electrical Engineering at the Faculty of Mathematics Chemistry, Physical in the UTM, Portoviejo, Ecuador. Professor currently working on his doctoral work on the topic of artificial intelligence for efficient application to university facilities.