RESEARCHERID
THOMSON REUTERS

[Rossi* 4(9): September, 2017] ISSN 2349-4506
Impact Factor: 2.785

Global Journal of Engineering Science and Research Management

ATMOSPHERIC DISCHARGE PROTECTION IN TELECOMMUNICATION STATIONS

Dariel Arruda Rossi*, Stéfano Frizzo Stefenon, Patrick Lopes Hanzen, Douglas Molter Ferreira
* Electrical Engineering Student, University of Planalto Catarinense, Brazil
Professor and Coordinator of the Electrical Engineering, University of Planalto Catarinense, Brazil
Electrical Engineering Post Graduate Student, Federal University of Santa Catarina, Brazil

DOI: 10.5281/zenodo.888557

KEYWORDS: Atmospheric discharges. Telecommunication stations.

ABSTRACT

This academic work presents as a central theme the importance that the protection equipment against atmospheric discharges has for telecommunication stations, it is a bibliographical research revision and the methodology is a qualitative research. The data was collected in scientific articles, books, dissertations, that deal with subjects related to the subject of this work. In addition, data collect, technical visits were made to telecommunication stations with the purpose of absorbing and inserting practical knowledge in this work. In the theoretical reference were addressed the subject, such as, atmospheric discharges, telecommunication stations and lightning protection systems. The research of this work deals in part with the phenomenon of atmospheric discharges, more specifically atmospheric discharges that may reach telecommunication stations, where equipment of significant values is installed. This work also concerns about how the protective equipment works. The data indicates that the telecommunication stations are the type of building most susceptible to be reached by an atmospheric discharge and it shows the importance that the systems of protection has for them. The data also indicates that these discharges are a phenomenon of nature still uncontrollable and unpredictable and that the protection systems only act by diverting the discharges from other equipment.

INTRODUCTION

The technological development enabled us to manipulate the electric energy, producing, transporting, distributing and consuming such energy and we also have the knowledge to manipulate and control electrical energy with high electrical potentials (15). However, when we talk about the electric energy that comes from nature, we are at the mercy of the weather, for example, in situations that electricity is destructive and uncontrollable (16). One of these situations, whose subject of this work encompasses, is the phenomenon of atmospheric discharges.

Atmospheric discharges are electrical discharges that are generated during rainstorms, by separating positive and negative charges within the clouds. With the accumulation of these charges the electric potential between the cloud and the earth tends to increase until the moment when the dielectric strength of the air is broken, thus forming a "spark", which we know by lightning or atmospheric discharge. There are two types of atmospheric discharges between cloud and earth: positive discharges representing 10% of the cases and negative discharges representing around 90% of the cases (11). The cases of atmospheric discharges that will be approached in this research will be those that occur from cloud to earth, where the discharges are negative and reach buildings and equipment used by humans.

Overcurrent and over voltage are problems generated by atmospheric discharges, being currently considered a major cause of defects in electrical network equipment, stations, as well as other equipment that we use in our daily life (6). Therefore, the importance of the research of a electrical engineer in this subject as a promoter of better conditions of the protection of equipment, buildings and of the human being in general is emphasized. Given this, we will first discuss aspects of the concept of atmospheric discharges. Initially will be carried out the bibliographic review of the subject, in order to explore and absorb knowledge about the primary cause of the problem. Next, we will see which points in the system most attract the atmospheric discharges into a telecommunication station. Finally, we will see how the systems of protection against atmospheric discharges works, how they provide the protection for the telecommunication stations and how important these protection systems have for them.

From the need for more efficient tools and systems in security, the industry has been evolving and this subject has gained more and more notoriety in this environment (16)(17), research on more sophisticated and efficient safety equipment is increasing (18). The evolution of technology has brought more efficient systems, the search for alternative sources of energy has made the electricity system more balanced in view that there is a tendency in the system to become bidirectional with decentralized energy sources, where the consumer is also part of the generation (19)(20).

PROBLEM DISCUSS

The atmospheric discharges is a nature phenomenon of great destructive potential. Every year this phenomenon causes various forms of damages in electric networks, electronic equipment, herds and not counting a number of fatalities that happen in our country and in every place of the world (4)(21). Because of this and the advancement of technology, scientists have developed some theories about the working of atmospheric discharges.

These theories and published works about atmospheric discharges point to the fundamental work of the electrical engineer, in the sense of monitoring and work, in the protection of stations, networks and other buildings that may be reached by atmospheric discharges. Therefore, the performance of this professional can be useful when we study intensely about the way the effects of atmospheric discharges and the elements involved in all the spheres that surround this phenomenon of nature.

The economic damages vary in proportion to the intensity of the incident surges, so, the more intense the atmospheric discharge on a station, the greater are losses due to the burning of the equipment. Such equipment is often of high commercial value, causing significant losses to companies (13).

These facts highlight the importance and necessity of the study on the systems to protect against atmospheric discharges and the installation of protection systems capable of providing partial or total protection of personal equipment (5). Given these facts, we must question what is the importance that the Lightning protection systems has for the telecommunication stations and how theese works for prevent or reduce the damage the damage that may be caused?

Justificative

On a daily basis, faults in the supply of electricity or the media are a fact that causes great inconvenience to the supplier companies and their respective customers (14). An example of this is factory production that is dependent on electrical energy to enable its production, in addition to the need for quality communication to control certain processes and either a possible remote control or to interconnect branches to a matrix in a single operating system (1). The interest in the theme arises from the importance we have in our daily lives of being connected to the media, and the problems we face when we come across them without the convenience and convenience of them. In addition, the topic is interesting if we make an analysis of how many equipment we use directly and indirectly that need some kind of protection against lightning (2).

Objective

To study the cause and the operation of atmospheric electric discharges, based on the theoretical bibliography on the subject and on current references. The analysis of solutions pertinent to electrical engineering, in the sense of intervening in the problems that the atmospheric discharges causes in buildings and equipments and in the risk that this phenomenon leads to telecommunication stations.

METHODS

The research involved in this work is a bibliographical review and qualitative type research. This research will be divided into two parts: The first part is about the primary cause of the problem of atmospheric discharges and their effect on the protection systems installed in telecommunication stations, and this will be made entirely based on books, scientific articles and dissertations that involve this subject. The second part of the research will be related to the effect that the atmospheric discharges causes to the systems and their protection equipment, showing the importance of the protection systems, equipment that compose them and how it acts in a case of a discharge. This stage of the work will also be done through a bibliographic review, however, in this step will be inserted some

data collected through two technical visits made in two different types of telecommunication stations. During these technical visits, we will collect the necessary data on the way in which the equipment to protect against atmospheric discharges is installed and how these kind of devices works in case the station is discharged.

LITERATURE REVIEW

In this chapter, aspects will be approached around the theoretical framework that in this stage involves the phenomenon of atmospheric discharges. More specifically we will approach the formation of storm clouds where the atmospheric discharges originate, which are the primary cause of the problem of this work. In this chapter, we will also see how it is formed, what it is and what the phenomenon of atmospheric discharges is capable of causing to buildings built by the human being.

The Origin of Atmospheric Discharges

Some theories elaborated by the science that explain this phenomenon, although we are still in the phase of discoveries on this subject, since there is much to be discovered on the atmospheric discharges. Currently we can avoid these discharges with the help of protection equipment and produce them artificially in order to study this phenomenon and test new protection equipment such as the Cachoeira Paulista field of tests, together with the State University of Campinas - UNICAMP (17).

Atmospheric Discharges at Telecommunication Stations and Protection Systems

Telecommunication stations are composed of a set of equipment with the purpose of amplifying, repeating, directing telecommunication signals and converting the physical means of transport. These structures are usually mounted on the ground, but it is also common for them to be mounted on tops of buildings in large urban centers where the amount and height of buildings would impede or limit the communication of a station mounted on the ground.

According to the Brazilian law § 2º Article 60 of General Telecommunications Law – law nº 9.472/97, the telecommunications station is the set of equipment or devices, devices and other means necessary for the realization of telecommunication, its accessories and peripherals, and, where appropriate, the facilities that house and complement them, including portable terminals.

Discharge Entry Doors in the Stations

Telecommunication stations are often subject to lightning strikes. This is due to the fact that the telecommunication stations in some cases are located in the top of a mountain or in the majority they are in the urban perimeter, containing a grounded metallic structure with lower ground impedance that the other structures around him, having difference Significant height in relation to the ground and because they are connected to a mains and telephone network, subject to being hit by an atmospheric discharge at any time (8). Mobile radio stations are usually located in urban areas and have towers with a height of over 50 meters. There are also cases where the radio stations and the mobile stations share the same space, increasing the vulnerability of the equipment to an eventual atmospheric discharge. There are three common entry points of an atmospheric discharge at a telecommunication station. The first case, being the most common is when the discharge reaches the power supply network, the second case is when the discharge reaches the metallic structure of the support the antennas and cables the station and other less common is when the discharge enters the station through the communication cables that share the same poles of the electrical network (8).

Lightning System Protection and Fundamental Components

The Protection system against atmospheric discharges is a set of electrical equipment that has the function of blocking the effects of the atmospheric discharges that may reach the building or equipment where it is installed. It actually deflects the harmful currents that are capable of damaging the system. This deviation is made by conductors that are connected to copper bars buried in the ground, known as grounding rods (12).

To compose the protection systems against atmospheric discharges, are used the next equipments: SPD (Surge Protection Device) that protects the station when it is hit by a discharge in the power grids, the circuit breaker, the lightning arrester that is an equipment commonly found in two models and that are Electric-lightning arresters,

"Franklin" lightning arresters, and in some more specific cases, Faraday's electromagnetic shield or Cage is also used (12).

Lightning Grounding

Grounding an equipment or structure consists of connecting them through conductors to earth in order to drain the electric current. It may be used in case of current surges or in cases where the voltage fluctuates. This electrical behavior can affect the equipment operation causing damages (7). In a telecommunication station, just like any other protected structure, grounding is the fundamental component for lightning protection, because all the other protection equipments are connected through conductors to it. The importance of the grounding system stands out taking into account, that through it that the outbreak currents are drained to the ground. Grounding is done by copper electrodes buried in the soil. The length of the bars, as well as the distance, depth and number of bars used to make a lightning ground depends on the desired ground impedance and the impedance range of the ground where it is to be grounded. (6).

The grounding impedance is the resistance to the passage of electrons through conductors and grounding rods to the ground. This impedance is measured in ohms as any other impedance (7).

Landfill system inspections MUST be performed annually with ground resistance measurement. The exception to the rule will be applied whenever the situation of the installation does not allow, that is, measurements should not be made only where it is not possible to use the equipment due to lack of conditions to stick the rods in the soil for the execution of the testing and data collection required. However, all visible equipment and accessory inspections must be done (3).

Surge Suppressor Device - SPD

The basic principle of lightning protection systems in communication stations is to ground all the components that make up the station, including equipment housings, metal structures, power networks and communication networks that have metals as their physical means of transport. This is possible in all structures except for electrical conductors that need to have voltage different from the ground reference.

In order for these station components to be protected as well, it is necessary to install a device called SPD, or it is also called Surge Suppressor Device. In telecommunication stations it is connected to the input branch in the circuit breaker board.

The SPD is an electronic equipment that has as operating principle similar to the varistor. The only difference between the varistor and the SPD is that the varistor is a disposable electronic component, being able to withstand only one discharge, such as the zinc oxide varistor which is basically a high impedance resistor, which when subjected to a very high voltage it merges into a conductor and the SPD is a more complex set of electronic components that act in the event of an overcurrent, closing a contact between the conductor and the ground, diverting the overcurrent to earth (10).

When the SPD undergoes a discharge, it conducts current to earth and after the discharge it must return to the initial state if prepared for a next discharge. It is connected in parallel with the equipment to be protected, between the phase of the network that feeds it and the equipment grounding bar (3).

These electronic components are installed in parallel on the network with the equipment to be protected. In order for the varistor or SPD to function correctly, it is necessary for the equipment to contain a fuse or a circuit-breaker connected in series in the power phase, as they work together: The SPD Closes a short circuit, the fuse and or the circuit breaker open when the Surge, isolating the equipment from the network and the SPD drains the current generated in the phase to the ground before it crosses through inside the equipment. At the moment of a discharge it must close the contact between phase and ground, causing a short circuit, which will therefore turn off the circuit breaker that must precede it during the power phase. Any overcurrent that passes through the circuit breaker must be discharged by the SPD (3).

Lightning Arresters

Atmospheric discharges have a tendency to occur at the highest and closest points of the charged cloud. To avoid that these discharges reach, among other structures, the telecommunication towers, the lightning protection equipments are used. The lightning rod is a metal tip located as high as possible and connected to ground by a well grounded electrode. This grounding is necessary because it is the path through which the charges rise until they are closer to the cloud, creating higher fields that will break the dielectric stiffness. During discharge, grounding allows the radius to flow (6).

The objective of a lightning rod is to receive the atmospheric discharge before it reaches the building in which it is installed (9). The arresters for telecommunication station towers are Franklin type arresters, which are the same metal equipment installed on top of buildings, towers, bridges and sheds and are installed in an exclusive ground, separate from the ground to other devices. This system consists of a captor, which is a pointed metal, located at the highest point of the system. It directly suffers the discharge and directs it to the driver to decide. The deconducting conductor is isolated from the building by spacers and connected to the grounding rods, so that the discharge is directed to the earth without affecting the structure of the same (7).

Electromagnetic Shield

The electromagnetic shield (known as Faraday's Cage) consists of a grid-shaped conductor mesh that surrounds the environment to be protected. This type of armor was discovered by physical and chemical Michael Faraday. His experiment consists of a cage-shaped metal structure, in which the internal loads of the cage are zero regardless of any load applied to the external environment of the cage (9).

This type of equipment protects the equipment shelters of the stations in discharge cases near them, because the magnetic flux generated by these discharges can generate electric current in some conductor or electronic component and can damage it. The shielding has no effect on the inside of the shelters and so that this magnetic flux is drained to the ground by the grounding loops.

The shields are not so easily deployable because they require a fairly large investment in design and installation. It is based on the Faraday Cage concept where, if there is a continuous conductive surface surrounding a given area, the interior of it is completely immune to disturbances of external electrical or magnetic origin (3).

This shows that electromagnetic shielding is an equipment that has many advantages, but its installation in large structures or buildings may be unfeasible due to its cost of material (3). Its installation proves very efficient in the telecommunication stations, since the shelters of the stations are not very big structures and they contain very significant equipment of value.

RESULTS AND DISCUSSION

We conducted a study about atmospheric discharges that affect the mobile telecommunication stations and the effects they cause them. We chose this type of building to study its protection system because these stations are hit more often by atmospheric discharges than any other type of building. For a better understanding of this phenomenon of nature, we have made a bibliographical review on it, drawing on the theories developed by science to this day. We reviewed these theories, thus formulating a line of reasoning about the functioning of the phenomenon, which is the primary problem of this research; About the damage it is capable of causing, humanity and its buildings.

To associate this work with a practical application, we made two visits to telecommunication stations, accompanied by engineers and technicians responsible for installation and maintenance of these types of stations. In these visits we find explanations for some cases that the protection systems against atmospheric discharges were reached and damaged, but they made the protection of the equipment of the station.

The first visit was in a station located in the urban perimeter, accompanying a visit of the technicians and those in charge of the preventive maintenance of the same. The purpose of this visit was to identify and analyze the equipment of the station, as the form of installation and operation. The second visit was to a station located in the

rural perimeter and located on the top of a mountain, accompanying a visit of the responsible technicians who were doing a corrective maintenance, due to an atmospheric discharge that reached the station through the food network.

We made the first technical visit to a telecommunication station of a company that operates mobile signals. The station visited is located in the urban perimeter and surrounded by residences. At this station, a set of equipment was identified, including: radio transmitter, battery bank and motor generator, tower support and antennas, air conditioning system for cooling other systems, public network power system; Protection system of atmospheric discharges and shelters in masonry. Being a set of equipment of significant values and subject to be hit by an atmospheric discharge.

Through this visit, the composition, shape and assembly of the structure were observed in general. And more specifically, the focus was on the protection system, its equipment and grounding. First we performed the ground impedance measurement, noting that the ground of the visited station contained 2.2 ohms of impedance. According to the engineer responsible for the station, by installation standard, these types of buildings must contain a maximum of 2 ohms of ground impedance. The standard on the maximum value of ground impedance varies according to the company that installs it, however, by characteristics of certain soils, it may occur that the minimum value of ground impedance obtained exceeds excessively the value normalized by the company.

Still talking about the grounding of the station, we observed that the groundings of the telecommunication stations are composed of several interconnected groundings. Each grounding contains a set of rods that correspond to a room or component of the station.

According to the engineer responsible for the station, this grounding configuration is used so that the grounding of each component of the station contains the same impedance and so that the discharge is not drained only by the ground that contains the least impedance. This results in and reinforces the theory that atmospheric discharges always occur at points closest to the cloud that are grounded and offer less resistance to the passage of electrons. We made the second technical visit to a telecommunication station of a signal operator located in the Santa Catarina plateau. The station visited is installed on top of a mountain. The station contains an antenna support tower about thirty meters from the base and a coupled motor-generator system in case of prolonged power failure by the local electricity distribution concessionaire.

The visit made by the technicians to the station had the purpose of performing a maintenance caused due to an atmospheric discharge that reached the same. During maintenance, some protective equipment such as SPDs and circuit breakers have been replaced.

The grounding of this station is poor with a ground impedance of 19.7 ohms. The deficiency of this grounding is due to the characteristic of the soil of the region, which in turn presents itself as a rocky soil. Soils composed of rocks generally provide a high resistance to the passage of electrons and when installing a ground in these regions it can be observed that the impedance does not decrease, even increasing the number, size or depth of the rods. This is due to the fact that each type of soil has an impedance range.

In this second visit we observed the effects of a discharge that reached the station through the phase of the mains. This discharge destroyed the equipment of the power supply board. Due to the use of the outbreak protection equipment the discharge did not affect the equipment any equipment of the station. Through the data cited during the development of this research we observed that the systems to protect against atmospheric discharges are fundamental equipment for the telecommunication stations, as well as for any other type of building made by the human being.

We observed this importance when studying the phenomenon of atmospheric discharges better, because when we imagine the immensity of nature that composes this phenomenon and compare it with the fragility that constitutes the electrical equipment and structures that we construct, we easily find arguments that explain the importance of an equipment Capable of withstanding and deflecting very high voltages and current.

We have found that the destruction capacity that an atmospheric discharge is capable of causing is the answer to the importance that the systems of protection against atmospheric discharges have to the stations of telecommunication, therefore, the importance is in the capacity that these equipment have to avoid the destruction Of telecommunication station equipment. We have also found that protective equipment prevents damage that lightning is capable of causing, but does not prevent discharges. Protective equipment only diverts them from other equipment because we have found that the principle of operation of any protection system for this is to divert the surge current generated by the atmospheric discharges to earth before the current flows through an equipment or reaches a person or living being near the station.

CONCLUSION

In electrical engineering courses, as well as other courses involving electricity, we learn that there are three ways to generate electricity or to electrify matter: electromagnetic induction, contact and friction. In this work we study one of these ways that is electrification through friction. Friction electrification is the way through which storm clouds carry to generate the atmospheric discharges.

This phenomenon of nature forces millions to be spent every year on maintenance of electrical networks, replacement of electronic equipment, electrical structures in general. But this problem could be worse if it were not for the technological advancement in the area of engineering in terms of protection against atmospheric discharges.

At the moment of history which we are inserted we can still consider ourselves partially lay when we deal with the phenomenon of atmospheric discharges, since there is still much to be discovered about them and as we investigate, we discover that mankind only knows this phenomenon theoretically. We have learned to produce them artificially with the intention of studying them, although in these cases we can partially defend ourselves from their effects, since this experiment is totally uncontrolled.

This fact seems incredible or satisfying to some people, but looking at this from the point of view of electrical engineering, with the need to reduce maintenance in electrical networks and equipment, it will be better if one day we can be able to develop protective equipment capable of to withstand an unlimited number of atmospheric discharges without the need for frequent replacement, as is the case with SPD equipment that is commonly replaced with every discharge it receives. With the immediate increase of the generation of electric energy, one day it would be possible to dominate or control the atmospheric discharges, making this phenomenon of nature work in our favor generating the energy we need.

Another aspect that could be a research objective in the area of electrical engineering would be the viability of the implantation of the systems of protection against atmospheric discharges in the telecommunication stations, in order to show what is the percentage of the total investment of a telecommunication station that these equipment represent.

The facts mentioned above reflect how important it is to use the equipment and systems to protect against atmospheric discharges in any and all buildings or equipment used by humans, as these equipment protects all types of systems, equipment and buildings that we build and use. In addition, they protect something much more important that is the people integrity.

REFERENCES

1. F. R. Agostinho et al., "Estudo sobre a viabilidade financeira na atualização tecnológica de uma planta fabril: Utilização de motores elétricos de alta eficiência e iluminação LED," in *Revista Espacio*s, vol. 38, no. 12, pp. 5-17, 2017. Available in: http://www.revistaespacios.com/a17v38n12/17381205.html
2. J. P. Américo et al., "Um Estudo Qualitativo das Técnicas Utilizadas para Medição e Localização de Descargas Parciais em Transformadores de Potência," in *Revista Espacios*, vol. 38, no. 34, pp. 14-25, 2017. Available in: http://www.revistaespacios.com/a17v38n34/17383414.html
3. R. B. Cardoso, "Requisitos Básicos Para os Sistemas de Aterramentos e Proteção Contra Surtos em Instalações do SISCEAB," Ministério da Defesa, Departamento de Controle do Espaço Aéreo, 2010.

4. F. P. Galli, S. F. Stefenon and J. P. Américo, "Análise de Curto-Circuitos Transitórios em Linhas de Transmissão Utilizando o Software UDW," in *Revista Espacios*, vol. 38, no. 34, pp. 11-21, 2017. Available in: http://www.revistaespacios.com/a17v38n34/17383411.html
5. A. Heilmann, "Avaliação Do Sistema De Detecção De Descargas Atmosféricas Em VLF - Zeus No Brasil," in Universidade de São Paulo, 2006.
6. F. Marcarine, "Proteção Contra Descargas Atmosféricas Utilizando Para-raios de Óxido de Zinco," in Universidade Federal de Viçosa, 2012.
7. G. F. Nicolau, Toledo, Ramalho Jr. and J. Ivan "Os Fundamentos da Física" Editora Moderna, São Paulo, 2005.
8. M. M. Pariona, "Simulação da Difusão do Zinco e do oxigênio, e Análise da Durabilidade de Varistor de ZnO Utilizando o Planejamento Fatorial," in Universidade Estadual de Ponta Grossa, 2000.
9. Rindat, "Rede Integrada Nacional de Detecção de Descargas Atmosféricas," Available in: http://www.rindat.com.br/
10. R. V. Stéfani, "Metodologia de Projeto de Sistema de Proteção Contra Descargas Atmosféricas Para Edifício Residencial" in Universidade de São Paulo, 2011.
11. F. Righez et al., "Análise de Viabilidade Técnica e Financeira de um Site de Internet Banda Larga Fixa", in *Revista GEINTEC - Gestão, Inovação e Tecnologias*, vol. 6, no. 4, pp. 3537-3552, 2016. doi: 10.7198/S2237-072220160004008
12. S. Frizzo Stefenon, J. R. de Oliveira, A. S. Coelho and L. H. Meyer, "Diagnostic of Insulators of Conventional Grid Through LabVIEW Analysis of FFT Signal Generated from Ultrasound Detector," in *IEEE Latin America Transactions*, vol. 15, no. 5, pp. 884-889, May 2017. doi: 10.1109/TLA.2017.7910202
13. S. F. Stefenon, L.H. Meyer and F. H. Molina, "Analysis of the Ultrasound Emitted from Defective Insulators," in *International Conference on Condition Monitoring and Diagnosis (CMD)*, Jeju Island, 2014.
14. S. F. Stefenon, L. H. Meyer and F. H. Molina, "Real Time Automated Diagnosis of Insulating System Employng Ultrasound Inspection," in *International Conference on Electricity Distribution*, vol. 23, pp. 1-4, Lion, 2015.
15. C. F. Barboza, "Campos Eletromagnéticos Produzidos Por Descargas Atmosféricas: Uma Abordagem Analítica no Domínio do Tempo," in Universidade Federal de Minas Gerais, 2009.
16. C. A. Avila Neto, et al., "Aplicação dos 5S e das Ferramentas da Qualidade para Gestão de Riscos da Segurança e Saúde no Trabalho," in *Revista Espacios*, vol. 38, no. 17, pp. 23-40, 2017. Available in: http://www.revistaespacios.com/a17v38n17/17381723.html
17. C. A. Avila Neto, et al., "Aplicação do 5W2H para criação do manual interno de segurança do trabalho," in *Revista Espacios*, vol. 37, no. 20, pp. 19-31, 2016. Available in: http://www.revistaespacios.com/a16v37n20/16372019.html
18. K. Ramos, et al., "Alert and protection system for children in vehicles," in *Business and Management Review*, vol. 5, no. 10, pp. 01-07, 2016. Available in: http://www.businessjournalz.org/articlepdf/BMR-510004-August%20-2016-5(10)-a.pdf
19. J. L. Barp et al., "Study on Small Wind Power Generator," in *Business and Management Review*, vol. 5, no. 10, pp. 21-30, 2016. Available in: http://www.businessjournalz.org/articlepdf/BMR-510005-August%20-2016-5(10)-c.pdf
20. D. S. Garcia et al., "A Feasibility Study on the Application of Photovoltaic Panels as Supplementary Power Generation for Residences in Serra Catarinense," in *Business and Management Review*, vol. 5, no. 10, pp. 08-20, 2016. Available in: http://www.businessjournalz.org/articlepdf/BMR-510003-August%20-2016-5(10)-b.pdf
21. T. I. A. H. Mustafa et al., "An analysis of the performance of power circuit breakers using a non-invasive system," *IEEE/PES Transmission and Distribution Conference and Exposition (T&D)*, Dallas, TX, 2016, pp. 1-4. doi: 10.1109/TDC.2016.7519976