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The Origin, Cause and Effect Methodology - OCEM applied to electrical faults or electrical accidents

Metodología Origen, Causa, Efecto – MOCE – aplicada a fallas eléctricas o accidentes eléctricos

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Abstract

This paper deals with the analysis of a methodology based on the philosophical categories Origin, Cause and Effect - OCEM concepts, applied to electrical faults or electrical accidents. The OCEM methodology proposed in this article is essential in any assertive diagnosis and solutions of an electrical failure or accident. According to the reports frequently delivered by electric power companies in Colombia, these generally report an atmospheric electrical discharge or lightning as the Cause of a failure or output of a transmission line. However, this is a conceptual error that leads to non-assertive solutions. The same happens, in general, in reports of electrical failures or electrical accidents whose origin is lightning strikes.

Keywords: Origin; cause; effect; electrical faults or electrical accidents

Resumen

Este artículo trata del análisis de una metodología basada en las categorías filosóficas de Origen, Causa y Efecto - MOCE, aplicada a fallas eléctricas o accidentes eléctricos. La metodología MOCE propuesta en este artículo es fundamental en cualquier diagnóstico y soluciones asertivas de una falla o accidente eléctrico. Según los informes que entregan con frecuencia las empresas de energía eléctrica en Colombia, estas generalmente reportan una descarga eléctrica atmosférica o un rayo como Causa de una falla o salida de una línea de transmisión. Sin embargo, este es un error conceptual que conduce a soluciones no asertivas. Igualmente sucede, en general, en informes de fallas eléctricas o accidentes eléctricos que son originados por impactos de rayos

Palabras claves: Origen; causa; efecto; fallas eléctricas o accidentes eléctrico

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1. Introduction to the OCEM methodology

Philosophically, the categories are the fundamental logical concepts that reflect the links and the most general and substantial connections of the reality of a phenomenon that is intended to be analyzed [1]. The process of scientific knowledge of an object is complex, by virtue of which the knowledge of the singular of the experience is interpreted through the general.

The philosophical categories of Origin, Cause, Effect, express the relationship existing in an analyzed phenomenon, of which one, called Cause, inevitably produces the other, called Effect; This relationship is called a causal relationship or causality.

Etymologically, Origin is derived from the Latin term *orīgo* and refers to the beginning, the irruption, the emergence or reason for something. From this meaning, the term has multiple uses.

Cause, comes from the Latin *cause* and points to what is considered as the foundation of something.

Effect is what occurs as a consequence of a cause. The link between a Cause and its Effect is known as causality.

Causality is the relationship established between Cause and Effect. In its broadest sense, it is said that something is the Cause of an Effect, when the latter depends on the former; that is, the Cause is that which makes the Effect what it is. This can occur in many different ways and, therefore, it is not strange that a multitude of causes correspond to an Effect.

Methodologically, when trying to analyze a natural phenomenon or a scientific fact, using these three categories allows for successful results in terms of diagnosing an Effect.

Two necessaries but not sufficient conditions for A to cause B are:

- That A precedes B in time.
- That A and B are relatively close in space and time.

The OCEM methodology can be schematically represented in figure 1.

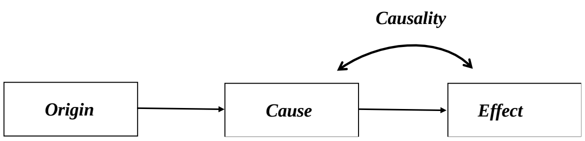

Figure 1. OCEM methodology represented schematically

2. Examples of analysis of the OCEM methodology

Next, 3 examples of application of the OCEM methodology are presented in a country like Colombia located in the area with the highest lightning activity in the world [9].

2.1 Failure of an electric transmission line

Let's see an example of the application of the OCEM methodology to the failure of an electric power transmission line [3].

According to the reports frequently delivered by electric power companies in Colombia, they generally report an atmospheric electrical discharge or lightning as Cause of a failure or output of a transmission line. However, this is a conceptual error.

For a better understanding of the application of the OCEM methodology, the images of figure 2 are presented. 2 a is the photograph of a lightning strike on an electric power transmission line and figure 2 b the sequence of phenomena that produces the impact of lightning.

Figure 2.a. photograph of lightning strikes on a power transmission line. Source: Royalty free.

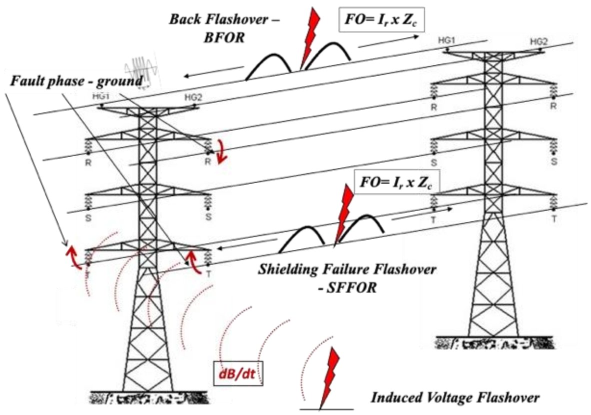

Figure 2b. Possible sequences of phenomena produced by a lightning strike. Source: own elaboration

Let's see: The Origin, the beginning of the fault can be a lightning that has 3 possibilities of streaked: on the shield wire, on one of the phases or on the ground.

If it hits the shield wire, an overvoltage is produced that can exceed the phase voltage and produce Back Flashover (BFOR), that is, the guard cable voltage (grounded) exceeds the phase voltage.

If lightning strikes a phase, Shielding Failure Flashover SFOR occurs.

But lightning can also strike the ground near the transmission line and, in this case, it produces a traveling wave of electromagnetic field variation (dB/dt), which, when coupled with the transmission line capacity, produces an induced voltage.

For the three types of lightning strikes that are the Origin, the Cause that occurs is an insulation failure in the insulator string, as shown in photo 2 a., when the lightning return current multiplied by the impedance of the system at the point of impact produces an overvoltage (BFOR, SFOR or Induced Voltage) that exceeds the insulation value of the insulator string and a fault occurs between phase and ground.

Therefore, the Cause, which originates the lightning strike, is a phase-ground fault, not a lightning strike, which is the Origin. This fault is an electromagnetic wave that travels through the transmission line and reaches the electrical substation where the protection devices are located, the relays that must clear the phase-ground fault. If the protection devices do not operate satisfactorily or the overvoltage exceeds the value at which the relays were calibrated, the transmission line will go out of operation.

In summary, the Origin was a lightning strike and only its parameters can be measured and behavior indices obtained. The Effect is a failure of the electric power transmission system and its consequences. Therefore, the solutions must focus on the Cause: how to improve the protections both in the substation and in the transmission line itself.

2.2 Accurate diagnoses and solutions with OCEM

When this type of analysis is achieved, it means an assertive diagnosis for an energy company that relatively easily leads to proposing solution analysis based on questions:

a. What was the magnitude of the return current of the lightning strike?
b. At what point of the transmission line did it impact?
c. What was the magnitude of the overvoltage that was generated?
d. What is the BIL of the insulator string at the point of impact?
e. Did the protections operate satisfactorily?

Nowadays all these questions can be answered, because in Colombia and in several countries of the world there is the technology and knowledge for it. Lightning localization networks are able to answer the first two questions, an engineer or student in the last semester is able to calculate the answer to question 3, knowing the data from questions a and b and the isolation of the chain of insulators and finally deduce if the protections operated satisfactorily or not, present an accurate diagnosis and propose solutions based on their analysis.

Subsequently, over time, this type of analysis can lead to another more statistical analysis that allows the energy company to take the corresponding technical measures for a system operation with greater reliability and better quality of the energy supplied.

The above analysis leads us to several conclusions:

1. The data collection formats for failure analysis of the energy companies must contain the origin data: Lightning return currents, impact site with distance error calculation or problems in the easement such as the fall of a tree, in the case of a distribution system, or accidents with the region's fauna, such as bird strikes. The latter requires a field visit. The Cause with data on the insulation

level of the insulator string and space for calculating the overvoltage and an analysis of whether the lightning strike produced BFOR, SFOR or Induced Voltage or servitude problems or accidents with wildlife and whether the protections operated satisfactorily.

2. An engineer or student in the last semester who is able to carry out the technical analysis of the failure.

3. A technical report that concludes with the diagnosis and possible solutions that allow the energy company to take measures that lead to the best operation of its electrical system, that is, a more reliable system and technological improvements.

This Origin, Cause Effect Methodology OCEM, is essential in any assertive diagnosis of an electrical failure or accident.

2.3 Other application examples with OCEM

A second example of application of the OCEM methodology is the technical analysis of a person who dies by electrocution in her house. What could have happened?

The analysis must start from the Origin, the beginning, the reason that generated the accident. It could have been due to an external or internal origin to the electrical system analyzed. The external origin refers to natural or personal elements external to the system and the internal origin refers to the electrical system inside the home or the electrical system that feeds the house where the accident occurred.

External origin means, for example, the impact of lightning on the electrical network that served the house in question or the fall of a tree on the electrical network or the impact of a bird on the transmission line. For this, it is necessary to know the atmospheric electrical activity of the area in question on the day and time of the accident and the information on the servitude of the electrical network that feeds the house in question.

Different internal origins can be analyzed in this hypothetical case: a maneuver within the electrical system, an internal failure of the system's insulation, a failure of the electrical system inside the house, etc.

The Cause, the rationale could have been, technically, a short circuit, a phase-to-ground fault if, for example, the impact of lightning on the electrical network or the fall of a tree or the impact of a bird on the electrical network, which, in either case, could have produced an overvoltage or an overcurrent in the system in question.

Based on the Origin, for example, when the branch of a tree impacts the distribution network, it causes a phase-ground electrical fault, which for this specific case we can consider as a short circuit, that is, an increase in current, which must be cleared. for the respective protections. And here the technical questions that must be answered by the company that provides the electric power service begin to appear: Did the protections work correctly? What were the conditions of the grounding system of the system, including the house? etc...

The Effect: the death of a person by electrocution. The person who dies must be evaluated by medical personnel, experts in necropsies in the hours following the events. It depends on the doctor that a good medical diagnosis is made to know the details of the death with forensic evidence.

A urine sample, for example, to determine the presence of myoglobin, is important for a more objective expert conclusion. Myoglobin is a muscle hemoprotein, structurally and functionally very similar to hemoglobin, whose function is to store and transport oxygen within muscle tissue. When the skeletal muscle suffers some damage, for example burns by electrical currents, myoglobin is released into the bloodstream and the kidneys are responsible for filtering it and eliminating it through urine.

With this methodology it is possible to obtain objective results in expert evidence of an electrical accident.

A third example of the application of the OCEM methodology occurred in the city of Bogota, Colombia, when a lightning struck a power transmission tower on the northern highway, as shown in figure 3. This lightning was captured by a lightning location system located on the premises of the National University of Colombia, in the city of Bogota.

In order to estimate the Lightning Peak Current in tropical zone, first negative Return Stroke Peak Currents were estimated from 167 electric field measurements performed with a parallel-plates antenna, using the location reported by the lightning locations systems installed in Colombia (LPATS, LLP) in order to calculate the distance from the strike point to the measurement station, [8].

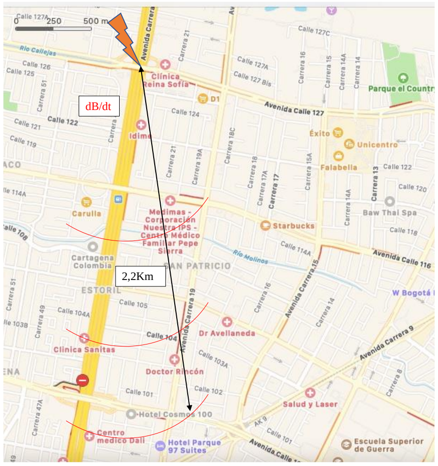

Figure 3. A lightning struck a power transmission tower on the northern highway and caused irreparable damage to the communications system of a hotel located approximately 2,2 km from the lightning strike site. Source: own elaboration

A comparison between peak currents obtained from radiation electric fields was made [2]. For the calculation, several return stroke models and empirical expressions that provide a relationship between peak current and peak electric radiation field f or a given distance were considered:

- Modified Transmission Line Model (MTL) [4]:
- Rakov-Willet Equation (R-W) [5]:
- Rakov- Dulzon Equation (R-D) [6]:
- Cooray's Return Stroke Model [7]:

A total of 167 distant measured events were analyzed. A separate comparison between field measurements and each of the location systems was performed. Common events are chosen on the basis of time correspondence between the parallel-plates antenna events and the corresponding LLS data.

As a result of this correlation, the location for each one of the common strokes was obtained using the geographical coordinates reported by the corresponding Lightning Location Network. With these data, the distance from the measurement station to the strike point was calculated.

Figure 4 presents eight lightnings captured by the same location system of the 167 measured events.

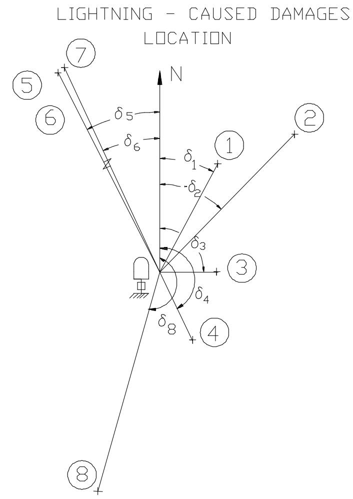

Figure 4. Eight lightnings captured by the same location system of the 167 measured events. Source: own elaboration

Table 1 corresponds to 8 events of the 167 measured at the national level.

Event #1 in Table 1 corresponds to the lightning stroked on an electric power transmission line and was the one that caused irreparable damage to the communications system of a hotel located approximately 2,2 km from the lightning strike site.

The correlation between the lightning impact on the transmission line and the damage to the Hotel's communications system was made by comparing the times (day, hour, seconds and milliseconds) reported by the lightning location system and the communications system. of the hotel, with a margin of error that we estimate to be 30 seconds.

When a lightning strikes the shield wire of an electric power transmission line, it generates a time-varying electromagnetic field that travels several kilometers through the air. This electromagnetic field generates a current and a voltage in a rod of more than 35 meters that was located in the aforementioned hotel building, fulfilling the function of grounding of the lightning rod and was located in the elevator shaft, less than a meter of the hotel's telecommunication system. The calculations of the variable electromagnetic fields, with the data measured 2,2 km from the hotel building, were enough to produce an overvoltage in the electronic circuits that produced irreparable damage to the telecommunication system.

Table 1. Data of 8 events of the 167 measured at the national level. Source: own elaboration

#	Date (d/m/y)	Time	Dist. (Km)	Angle	ITLM (kA)	I_R(kA)	Effect
1	12/02/93	16:12: 05.259	8,50	27°53'25"	6.42	5.63	Broken shield wire, burned optical fiber, electronic equipment damage in a hotel 2 km away.
2	25/02/93	14:31: 24.442	13,3	43°	53.2	57.5	Broken shield wire
3	25/02/93	13:56: 33.081	4,14	90°50'	37.3	39.5	Broken insulator string
4	25/02/93	14:26: 18.475	5,21	152° 58'05"	6.5	5.7	Exploded lightning arrester (SiC)
#	Date (d/m/y)	Time	Dist. (Km)	Angle	ITLM (kA)	I_R (kA)	Effect
5	01/10/92	22:59: 35.711	176,8	333°	34	36.3	Distance relay tripping
6	25/10/92	03:05: 49.980	175,6	333°	31.7	33.7	"
7	04/11/92	23:47: 49.354	159,4	335°	97.3	106.5	"
8	04/11/93	13:21: 05.129	163,5	196° 45'	15.3	15.5	Damaged electronic equipment

Notes: ITLM: Current calculated with the Transmission Line Model; IR: Current calculated using the formula derivate by Rakov [6] based on the measurement of the variation of the electromagnetic field dB/dt

Several conclusions can be deduced from this real example:

- A lightning rod located in a building or civil installation with ground conductors is not a guarantee of protection against lightning. On the contrary, the induced currents and voltages can be high enough to produce overvoltages and overcurrents in sensitive electronic circuits close to the down rod of the arrester, causing irreparable damage and are a high risk for people who are close to the grounding conductor of the lightning rod.
- In this real example, the Effect is clear (irreparable damage to the hotel's telecommunications system). The Cause was an overvoltage and an overcurrent that exceeded the protections of the telecommunications system, due to a variable electromagnetic field in time, traveling through the air due to the impact of lightning. And the Origin, the impact of lightning more than 2 km away.
- When the OCEM methodology is applied, the diagnosis of the case is clear and its solution is relatively easy
- In this case, the solution was to remove the lightning rod and its down conductors to the ground (although the insurance policy paid for the damage, because hotel had a lightning rod!!) and design and build a Faraday cage-type system that the hotel currently has for protection against lightning.

3 Conclusions

The OCEM methodology, based on the conceptual categories of Origin, Cause and Effect, aims to create in the consciousness of electrical fault analyst engineer's fundamental concepts of logic that reflect the relationships of the reality of a phenomenon that is intended to be analyzed, in order to achieve accurate diagnoses and solutions.

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5 Conflict of interests

The author explicitly declares that there is no secondary financial or professional conflict of interest, among others, in the preparation and writing of this paper.

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