v. 3, n. 38, 2023

Journal of
Engineering
Research

ELECTROMAGNETISM: APPLICATION OF PHYSICS IN ELECTRICAL ENERGY METERS[1]

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1. Scientific article presented to the IBRA Educational Group as a requirement for approval in the TCC discipline.

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Abstract: The electrical energy supplied by concessionaires to establishments and homes is measured by electrical energy consumption meters. From there, billing is carried out and an account is generated for the consumer to make payment. Among the meters used, the so-called electromechanical ones stand out, as they are present in most consumer units. In their operation, these devices use phenomena related to electromagnetism, a branch of physics that has applications in various areas, in addition to the aforementioned. Among the concepts applied in its operation is the principle of induction, in which two laws stand out: Faraday's Law and Lenz's Law. There are also principles related to electromagnetic force. Thus, understanding how the electromechanical electrical energy meter works, in addition to familiarizing people with equipment that is part of a large part of people's lives, illustrates the practical importance of this branch of physics, that is, electromagnetism.

Keywords: Electromechanical energy meter. Electromagnetism. Electromagnetic induction. Electric force.

INTRODUCTION

Electromagnetism has several applications in the modern world, especially when it comes to movements. Electric motors, the most emblematic example of these applications, are present in all sectors of society. These devices are found in industrial machines, in most household appliances and in people's cell phones. In addition to electric motors, countless other contributions are attributed to the concepts of electromagnetism.

One device in particular, which uses similar physical concepts to electric motors, is the electromechanical electrical energy meter. It is responsible for computing the amount of electrical energy that each consumer unit uses. The passage of current in a coil produces a series of movements that propagate through a gear system so that, at the end of a predetermined period, the amount of energy consumed is read and thus, it is generated, after the addition of certain taxes, the corresponding invoice to be paid.

Despite the gradual replacement of electromechanical meters by electronic ones, as it is an old technology, they are still widely used, which makes it important to understand how they work and the concepts of electromagnetism involved, in addition to relating the theory developed in a specific application, which ratifies the importance of the electromagnetism branch.

ELECTROMAGNETISM

Among the branches of physics, a discipline that studies natural phenomena, is electricity. This, in turn, is divided into three areas: electrostatics, electrodynamics and electromagnetism. This last application has the operating principle of electromechanical energy meters, through the phenomenon of magnetic induction.

MAGNETIC INDUCTION

An electric current, when circulating through a conductor, produces a magnetic field around that conductor. The opposite effect, that is, a magnetic field can generate an electric field capable of producing this same current. This connection is called Faraday's Law of Induction (HALLIDAY, RESNICK, WALKER, 2016).

In other words, in a conducting loop, connected in series with an ammeter, when it approaches a magnet (magnetic field), a current value will be detected in the meter. This happens because as the magnet approaches, the field lines that reach the circular area of the loop vary, that is, the flux is variable. And it is precisely this variation in magnetic flux that induces an electromotive force and, consequently, an electric current in the loop, which is detected by the ammeter.

The direction of an induced current is such that the magnetic field produced by the current opposes the variation in the magnetic flux that induced the current. The induced electromotive force has the same direction as the induced current. This is Lenz's Law, according to FERRARO, TORRES, PENTEADO, 2018.

Mathematically, Lenz's Law can be represented by the following equation:

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

Where:

Ɛ: Induced electromotive force, in Volts:

F_B: Magnetic flux through an area limited by a loop, in Weber;

t: Time, in seconds.

MAGNETIC FORCE

According to (Ramalho, Ferraro and Toledo, 2009), moving electric charges – electric current – create a magnetic field. As these charges are inserted in a second magnetic field, there will be an interaction between these two fields, creating forces that act on these charges – magnetic forces, whose direction is perpendicular to the direction of the electric current that circulates through the conductor.

Miyasaka states that the magnitude of the electromagnetic force, which acts on a conductor, is given by the following equation. (2020).

$$F = B.i.l.\sin\theta$$

Where:

i: is the current passing through the conductor;

l: conductor length;

B: magnetic field;

α: It is the angle between *B* and the direction of *il* in the space.

Just like any other force, magnetic force also produces acceleration in a body at rest.

ELECTRICITY METERS

The measurement of electrical energy is used, in practice, to enable the supplying entity to adequately bill the amount of electrical energy consumed by each user, within an established trade, as electrical energy is a commodity like any other (MÍNGUEZ, 2007). This measurement is carried out using devices called electrical energy meters.

TYPES OF ELECTRICAL ENERGY METERS

There are two types of meters: electronic and electromechanical. The first is in the process of being implemented and replacing the electromechanical one, as it is more modern and intelligent, with greater interactivity in measurements, which can even be carried out remotely. Its operation uses the Hall effect, in addition to microprocessors to record and store the electrical energy consumed. The second type of meter, although less

modern, can still be found in most homes and commercial establishments. In his thesis, Gabriel Miyasaka states that currently, around half of the Brazilian measurement system is still made up of electromechanical meters (MIYASAKA, 2020).

Below is an image of an electronic and an electromechanical meter:

Image: Electronic electricity meter

Source: Eletra energy solutions[2]

Image: Electromechanical electrical energy meter

Source: Professor Cide[3]

ELECTROMECHANICAL ELECTRICAL ENERGY METERS

DEFINITION OF ELECTROMECHANICAL ENERGY METERS

These meters are considered electric induction motors, which use the interaction between magnetic fluxes to move a rotor – a movable disc. (MAIA, 2019).

Ramalho, Ferraro and Toledo state that what we commonly call a light clock is actually a meter of electrical energy consumed by loads in the location where this meter is installed. In it, a horizontal disc rotates when electrical energy is being consumed. Therefore, the greater the energy consumption, the greater its angular velocity. (2009).

LOCALIZAÇÃO DOS MEDIDORES DE ENERGIA ELETROMECÂNICOS

In relation to the installation of electricity meters, according to Aneel's PRODIST, in its paragraph 1, item 3.1.1.1,

> Once the supply order has been made, the distributor will inform the interested party of the obligation to install, in appropriate places with free and easy access, boxes, panels, panels or cubicles intended for the installation of meters, measuring transformers and other distributor devices, necessary for the installation of the electrical energy measurement system and protection of these installations.

In other words, the electrical energy meter must be part of every input standard, which, according to Cavalin and Cervelin, can be defined as the entire set from the input branch, particular pole or spike, boxes, protection devices, grounding, conduits and hardware, the responsibility of consumers, prepared in a way that allows the connection of consumer

2.http://www.eletraenergy.com/br/portifolio/20-medidores-de-energia/medidores-residenciais/linha-cronos/216-cronos-7023-2-5

3. http://profcide.blogspot.com/2010/06/o-medidor-de-energia-eletrica.html

units to the concessionaire's network. (2017).

See image below:

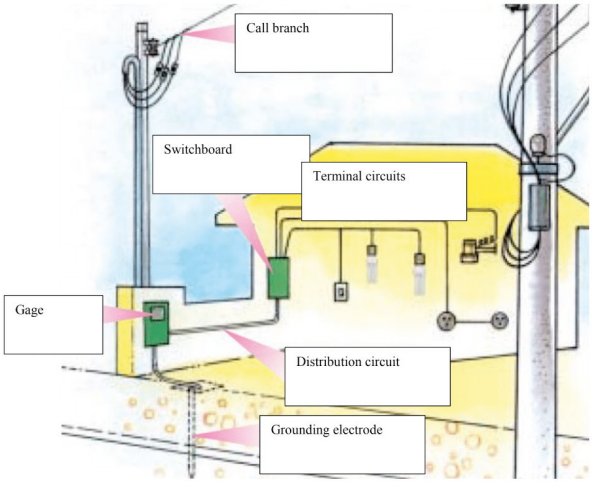

Image: location of an energy meter in a consumer unit

Source: Pinterest[5]

WORKING PRINCIPLE OF ELECTROMECHANICAL ENERGY METERS

The movement of the rotor – meter disc – is responsible for measuring electrical energy consumption, which is stored in the recorder. This is the increment in values as the disk rotates (MAIA, 2019). This mechanism occurs through the transmission of movements between gears present in the meter, including those that make up the recorder.

In more detail, inside the meter there are two coils, one for voltage, the other for current. The first is powered by the voltage (potential difference) of the network (220V, 380V, etc.) where a magnetic field is generated.

The operation of the electromechanical meter occurs when an electrical current, drained by the load that uses electrical energy, causes current to enter through the meter's terminal, which runs through the current coil. When the electric current passes through, induced and phase-shifted magnetic fields are generated by the current that will be consumed and measured. The interaction of these fields with the field produced by the tension coil produces magnetic force that affects an extremely light disc, located between the two coils, which begins to perform a circular movement.

Connected to the center of this disc is an axis, which also starts to move with the same angular speed as the disc. This shaft, which contains a worm-type screw, transmits this movement to a spur gear that is connected to gears with different radii – each representing units, tens, hundreds and thousands. This set makes up the recorder, determining the total energy consumed, given in kilowatt-hours (kWh), in the determining period. Below are two views of the internal schematic of an electromechanical meter.

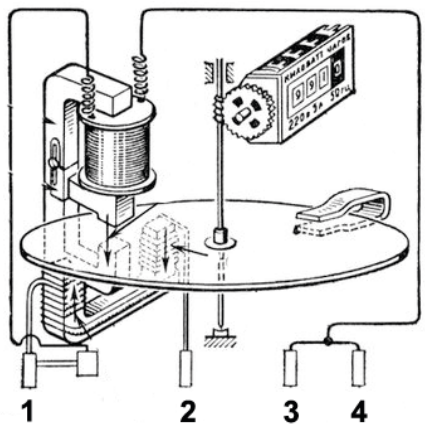

Figure: Schematic of an electromechanical meter

Source: New Electronics [4]

The installation of the meter in the circuit occurs in series with the load – equipment that uses electrical energy – and with the electrical network (line), that is, the current that enters through the line is the same current that leaves towards the load, as long as the device does not present any defect, such as current leakage or fraud.

4. https://blog.novaeletronica.com.br/medidor-de-energia-eletrica/

CONCLUSION

It was found that electromagnetism, especially concepts related to magnetic induction, revolutionized the modern world. Electric motors are one of the most obvious examples of this, as they are present in practically every home and industry, comprising household appliances, cell phones, toys, automobiles, among others.

It was demonstrated that one of the most familiar applications of the concepts of electromagnetic induction is in the operation of electromechanical energy meters. This equipment, despite being gradually replaced by electronic equipment, is still extremely important, as it accounts for the majority of electrical energy consumed in cities.

The way this expense is measured showed, in a clear and objective way, the applicability of electromagnetism, more precisely, of the concepts of electromagnetic induction and electromagnetic force.

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