HERTZIAN MOTOR: An innovative method to obtain an energy efficiency of 90%, in savings in single-phase active energy (kwh), if the "Fan Law" is applied to PSMSM-type synchronous motors without the need to apply the use of Variable Frequency Drives (VFD).

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Resume.

This paper proposes how to reduce the consumption of active electrical energy (kwh) by 90.3% while maintaining the same mechanical work speed (RPM) at variable torque loads (fans or air-fluid blowers, centrifugal pumps are not included). of water and similar fluids), by using the "Fan Law" in an innovative way in PMSM-type synchronous motors (a comparative study never before carried out on the Fan Law). The work is carried out comparatively between brushless a-synchronous motors with starting loop (or motor with a short-circuited loop) versus brushed a-synchronous motors and PMSM-type synchronous motors without the need to use VDF (variable frequency drives), simplifying technology (electronics) and saving costs in an innovative way (R+D+i). The case study was developed on a design applied to a centrifugal air extractor/blower with PMSM/IPM type synchronous motor. Applying one of the fan affinity laws –with the impeller diameter 10.5 (mm) constant- the electrical power absorbed by the blower motor is proportional to the cube of the shaft speed: $P_1/P_2 = (N_1/N_2)^3$. Being "P" power (Watts) and "N" speed (RPM). Carrying out a comparative study between power (watts), active energy consumption (kwh) and rotational speed (RPM). This has a direct impact on the costs of residential and commercial single-phase active electrical energy consumption, measured in kilowatt-hours (kwh). Carrying out a comparative study between three (3) types of alternating current (AC) electrical machines, according to the NEMA (National Electrical Manufacturers Association); AC motors fall into three (3) categories. One (1), synchronous motors (Syncrhonous Motor) of three types: (1a) excitation by DC (DC Excited Motor), (1b) permanent magnet (Permanent Magnet Motor) and (1c) reluctance motor (Reluctance Motor) or motor Step by Step. Two (2), asynchronous induction motors of two types: (2a) Squirrel-Cage Induction Motor and (2b) Wound-Rotor Induction Motor. Three (3) series-wound motor (Series-Wound Motor) also called universal motor (they have carbons).

Keywords: Energy efficiency, single-phase active energy, kWh, electricity saving, Fan Affinity Law.

Introduction.

Requires a brief description or classification, a special type of electrical machine used in this work: electric motors. Since it transforms electrical energy into mechanical.

Considering the nature of the type of alternating current (AC) used, according to the NEMA (National Electrical Manufacturers Association) or National Association of Electrical Manufacturers; AC motors fall into three (3) categories. One (1), synchronous motors of three types: (1a) DC Excited Motor, (1b) Permanent Magnet Motor and (1c) Reluctance Motor or Motor Step by Step. Two (2), asynchronous induction motors of two types: (2a) Squirrel-Cage Induction Motor and (2b) Wound-Rotor Induction Motor. Three (3) Series-Wound Motor also called Universal Motor (they have carbons).

Introduction.

In 1824, the French physicist François Arago formulated the existence of rotating magnetic fields, called Arago rotations. By manually turning switches on and off, Walter Baily demonstrated this in 1879, effectively the first primitive induction motor. The first commutatorless single-phase AC induction motor was invented by the Hungarian engineer Ottó Bláthy.

The first AC commutatorless polyphase induction motors were invented independently by Galileo Ferraris and Nikola Tesla. Galileo Ferraris described an induction machine with a two-phase stator winding and a solid copper cylindrical armature in 1885. In 1888, Nikola Tesla received a patent on a two-phase induction motor with a short-circuited copper rotor winding and a two-phase winding. Developments of this design became commercially important.

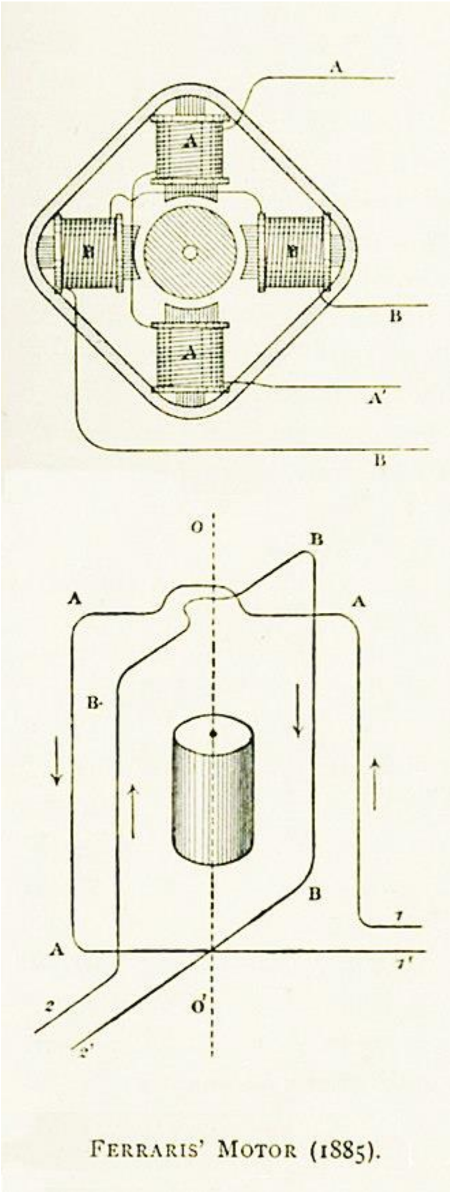
In 1889, the Polish-Russian Mikhail Dolivo-Dobrovolsky invented the squirrel-cage rotor induction motor. It is not an objective to describe the structure and theory of operation of the so-called "squirrel cage".

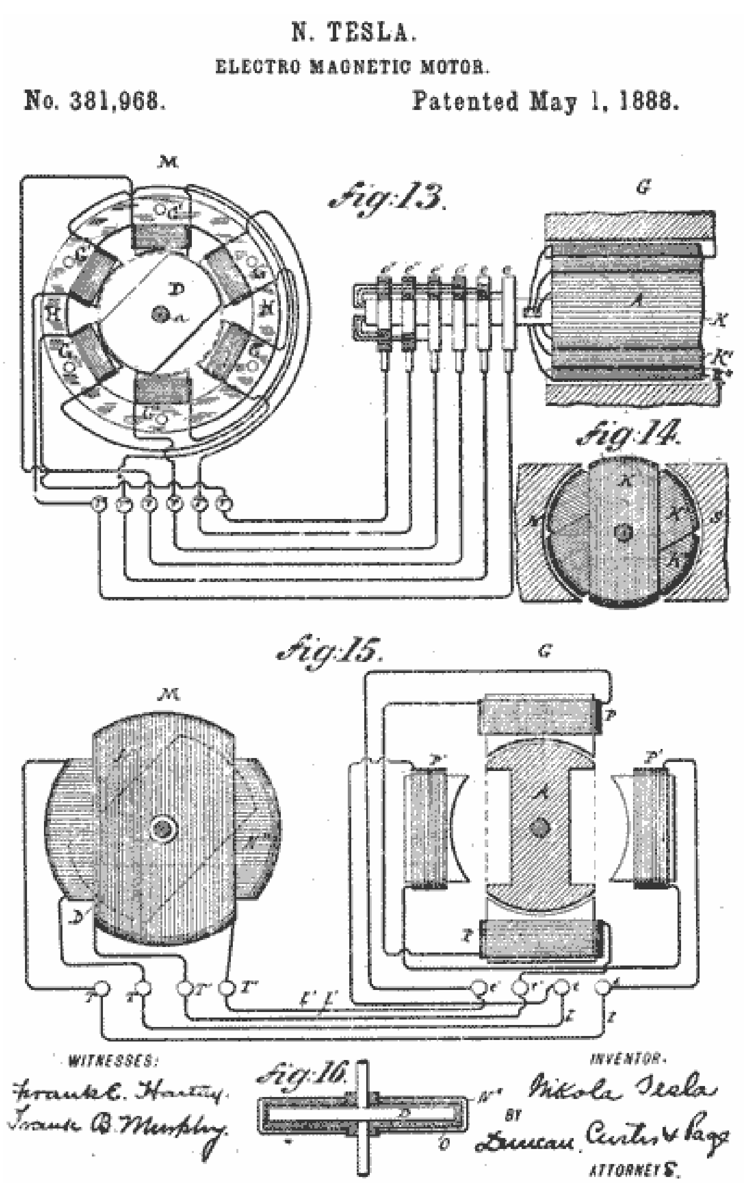
The difference between the induction motor and the universal motor -as we will see later- is that in the induction motor the rotor winding is not connected to the excitation circuit of the motor but is electrically isolated. It has full-length conducting bars embedded in grooves at uniform distances around the periphery. The bars are connected with rings (in short circuit) to each end of the rotor. They are welded to the ends of the bars. This assembly resembles small rotating cages for exercising pets such as hamsters and is therefore sometimes called a "squirrel cage", and induction motors are called squirrel cage motors.

The squirrel cage motor consists of a rotor made up of a series of metallic conductors (usually aluminum) arranged parallel to each other, and short-circuited at their ends by metallic rings, this is what forms the so-called squirrel cage due to its graphic similarity to a squirrel cage. This 'cage' is filled with material, usually stacked sheet metal or aluminium. In this way, an n-phase system of conductors is achieved (where "n" is the number of conductors, commonly 3) located inside the rotating magnetic field created by the stator, thus having a very efficient physical system, simple, and very robust (basically, it does not require maintenance as it lacks brushes).

By the end of the 19th century, induction motors were widely applied in the growing alternating current electrical distribution systems. The new application of alternating current in the production of rotary motion was made known almost simultaneously by two experimenters, Nikola Tesla and Galileo Ferraris, and the subject has attracted general attention because no commutator was required.

The first AC commutatorless polyphase induction motors were invented independently by Galileo Ferraris and Nikola Tesla, the former having demonstrated a working motor model in 1885 and the latter in 1887. Tesla applied for US patents in October and November 1887 and Some of these patents were granted in May 1888.





Figures 1 and 2. On the left is the first AC motor in the world from 1885 which is attributed to the Italian electrical engineer Galileo Ferraris, it predates the patent no. 381968 of 1888 of the Serbian electrical engineer Nikola Tesla. While Italian professor Ferraris manages to build a small two-phase induction motor in 1885, Tesla knows nothing of Ferrari's induction motor and reinvents it soon after. Source (1): https://archive.org/details/polyphaseelectri00thomuoft/page/88/mode/2up Source (2): https://patents.google.com/patent/US381968

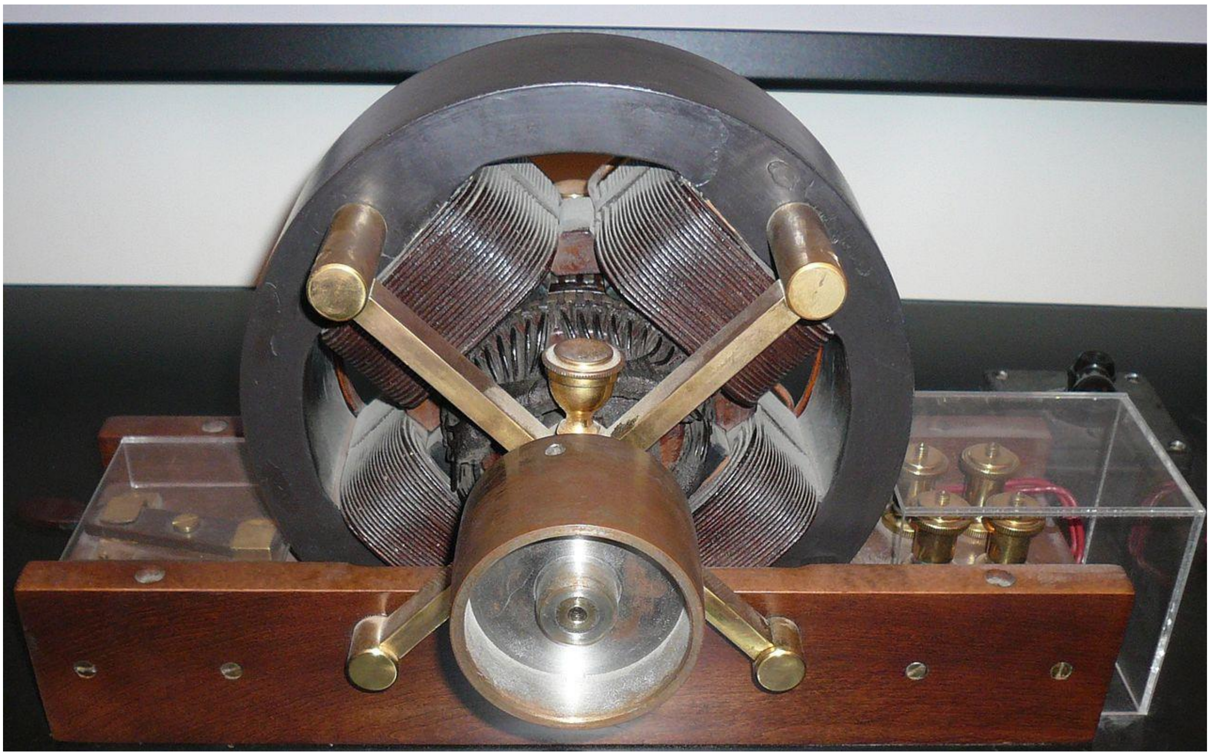


Figure 3. A model of Nikola Tesla's first induction motor in the Tesla Museum in Belgrade, Serbia. Fountain:https://commons.wikimedia.org/wiki/File:Tesla%27s_induction_motor.jpg

In May 1888, Tesla submitted the technical paper A New System for AC Motors and Transformers to the American Institute of Electrical Engineers (AIEE) describing three types of four-pole stator motors: one with a four-pole rotor that forms a reluctance motor without a self-start, another with a wound rotor forming a self-start induction motor, and the third a true synchronous motor with a separately excited DC supply to the rotor winding.
The asynchronous motor is made up of a rotor, which can be of two types: (a) squirrel cage; (b) winding, and a stator, in which the inductor coils are located. These coils can be single-phase or three-phase. According to Ferraris' theorem, when a system of currents circulates through these coils, a rotating magnetic field is induced that surrounds the rotor.
In the special case of the three-phase asynchronous motor, which is formed by a three-phase wound stator 120º out of phase with each other in space. According to Ferraris' theorem, when a system of balanced triphasic currents circulates through these coils, whose time lag is also 120º, a rotating magnetic field is induced that surrounds the rotor.
A three-phase motor is an electrical machine whose consumption of electrical energy is formed by three single-phase alternating currents of equal frequency and amplitude (and therefore effective value), which have a phase difference between them of 120 electrical degrees, and are given in a determined order. Each of the single-phase currents that make up the system is designated with the name of the phase.

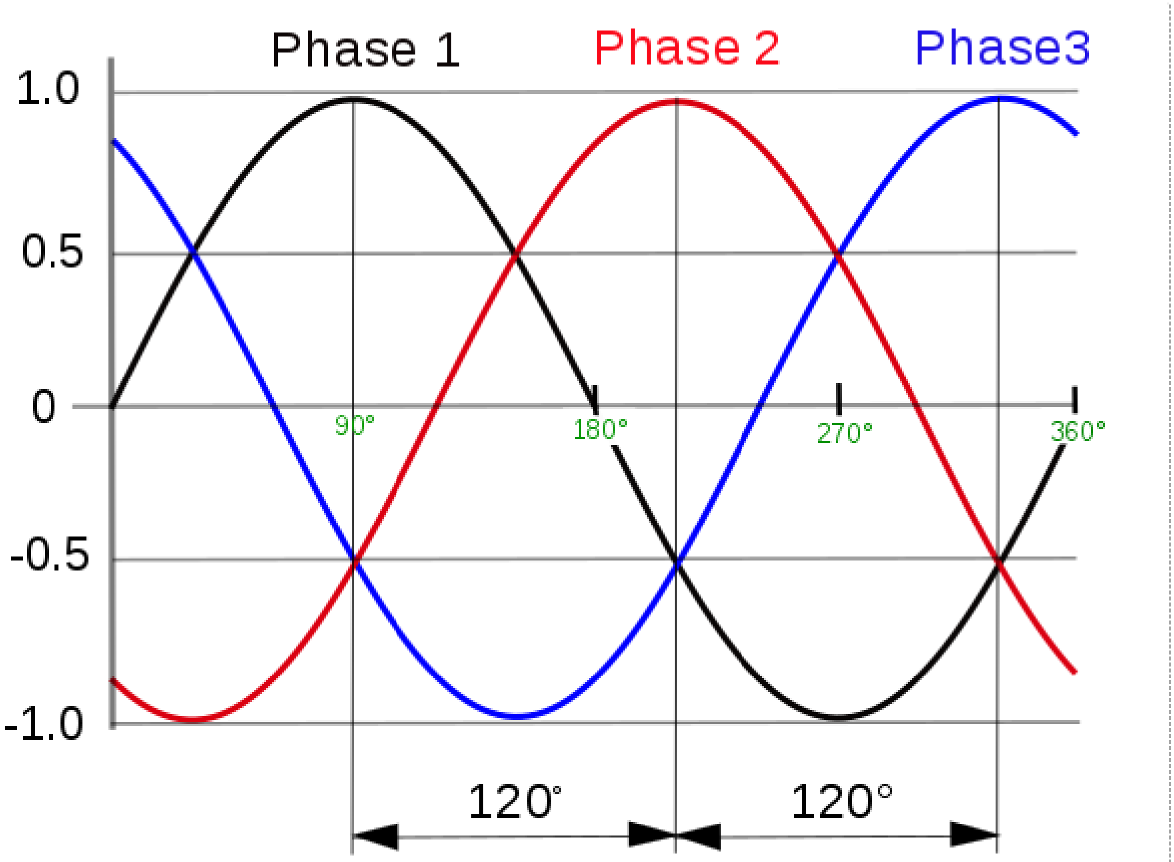


Figure 4. Voltage in the phases of a balanced three-phase system. Between each of the phases there is a phase shift of 120°. A three-phase system of voltages is said to be balanced when their currents have equal magnitudes and are symmetrically out of phase. Depending on whether the start occurs with a star or triangle (delta) type connection, the voltage varies between 380/400 (Volts) and 230 (Volts) respectively. Fountain: https://commons.wikimedia.org/wiki/File:3_phase_AC_waveform.svg

This variable magnetic field will induce an electrical voltage in the rotor according to Faraday's law of induction:

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

In a very thin closed circuit in which the magnetic flux varies, an electromotive force (emf or electromotive force) proportional to the temporal variation of the flux is induced. The direction of the induced EMF is given by Lenz's Law.

In the case of an inductor with "N" turns, the above formula becomes:

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

Where:

V_{ε}, is the voltage (Volts) or induced electromotive force.

$\frac{d\Phi_B}{dt}$, is the time variation rate of the magnetic flux (Φ_B) in a loop.

The rotating magnetic field, at synchronous speed, created by the stator winding, cuts the rotor conductors, thus generating an induction magnetomotive force. The mutual action of the rotating field and the existing currents in the rotor conductors, originate an electrodynamic force on said rotor conductors, which make the rotor of the motor rotate.
The difference between the speeds of the rotor and the magnetic field is called slip or slip.
The asynchronous motor works on Faraday's principle of mutual induction. By applying three-phase alternating current to the inductor coils, a rotating magnetic field is produced, known as a rotating field, whose frequency will be equal to that of the alternating current with which the motor is fed. This field, when rotating around the rotor at rest, will induce electrical voltages that will generate currents in it. These will in turn produce a magnetic field that will follow the movement of the stator field, producing a couple or motor torque that makes the rotor rotate (principle of mutual induction). However, since induction in the rotor only occurs if there is a difference in the relative speeds of the stator and rotor fields, the speed of the rotor never catches up with that of the rotating field. Otherwise, if both speeds were equal, there would be no induction and the rotor would not produce torque. This speed difference is called "slip" and is measured in percentage terms, so this is the reason why induction motors are called asynchronous, since the rotor speed differs slightly from that of the rotating field. .

Slip in an electrical machine is the relative difference between the speed of the magnetic field (synchronous speed) and the speed of the rotor. The following expressions are equivalent to find the slip:

$$S = \frac{\omega_s - \omega_m}{\omega_s} . 100\% = \frac{n_s - n_m}{n_s} . 100\%$$

Where:

S, slip speed, expressed on a per-unit basis or as a percentage (%).
ω_s, synchronous angular velocity in radians per second (rad/sec).
ω_m, angular velocity of the rotor in radians per second (rad/sec).
n_s, synchronous angular velocity in revolutions per minute (RPM).
n_m, angular velocity of the rotor in revolutions per minute (RPM).

The slip is especially useful when we analyze the operation of the asynchronous motor since these speeds are different. The voltage induced in the rotor winding of an induction motor depends on the relative speed of the rotor in relation to the magnetic fields.
An induction motor or asynchronous motor is an AC electric motor in which the electric current in the rotor necessary to produce torque is obtained by electromagnetic induction of the magnetic field of the stator winding. Therefore, an induction motor can be made without electrical connections to the rotor. The rotor of an induction motor can be of the type (a) wound or of the type (b) squirrel cage.
Three-phase squirrel cage induction motors are widely used as industrial drives because they are self-starting, reliable, and economical. Single phase induction motors are widely used for smaller loads such as appliances and fans. Although traditionally used in fixed speed services, induction motors are increasingly being used with Variable Frequency Drives (VFDs) in variable speed services. VFDs offer especially significant energy savings opportunities for existing and future induction motors in variable torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are widely used in variable frequency, fixed speed drive applications.

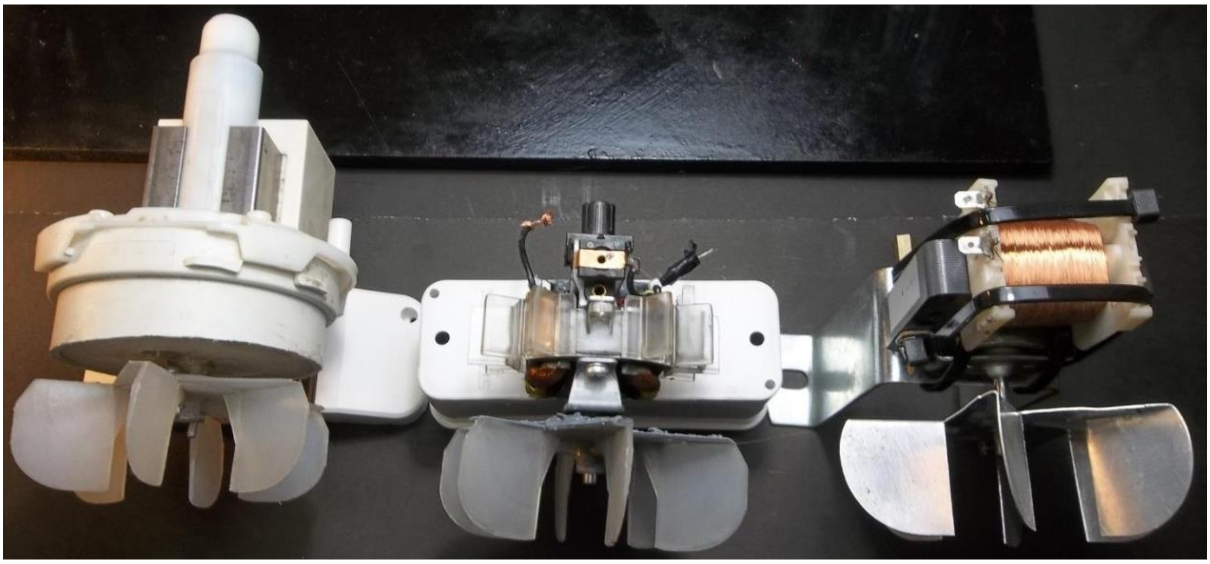


Figure 5. From left to right, electrical machines used in the experiment: (a) Syncrhonous Motor-Permanent Magnet type PMSM/IPM (Permanent Magnet Synchronous Motor/Interior Permanent Magnet) or permanent magnet synchronous motor (of ferrite), (b) Series-Wound Motor or Universal Asynchronous Motor and (c) Shaded-Pole Motor a type of AC asynchronous single-phase induction motor. The three (3) types of motors used have 10,5 (mm) blades to be subjected to their comparative study. Source: self made.

The years 1885 through 1889 saw the invention of the three-phase electric power system that is the basis for modern electric power transmission and advanced electric motors. Not a single inventor can be named for the three phase power system. There are several more or less well-known names that were deeply involved in the inventions: Bradley, Dolivo-Dobrowolsky, Ferraris, Haselwander, Tesla and Wenström.

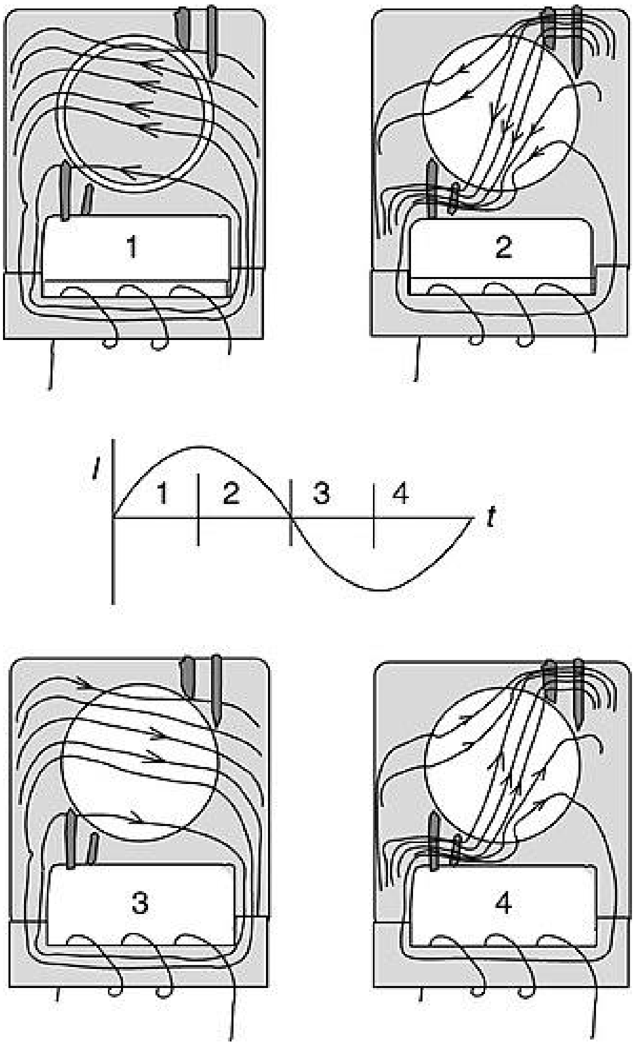
Shaded pole motor, a type of AC asynchronous single phase induction motor.

Shaded-pole motor or fragger's loop motor is a type of AC single-phase asynchronous induction motor, dating back to at least 1890. It can also be described as a small induction motor. of the "squirrel cage" type (Squirrel-Cage Induction Motor) in which the auxiliary winding consists of a ring or copper bar that surrounds a part of each pole. When single phase AC power is applied to the stator winding, due to the shading provided to the poles, a rotating magnetic field is generated. This single turn auxiliary winding is called a shading coil. Currents induced in this coil by the magnetic field create a second electrical phase by retarding the phase change of magnetic flux for that pole (a shaded pole) enough to provide a rotating two (2) phase magnetic field. The direction of rotation is from the unshaded side to the shaded (ring) side of the post. Since the phase angle between the shaded and unshaded sections is small, shaded pole motors produce only a small starting torque relative to the torque at full speed.

They require stator alterations, such as Shaded-pole, to provide starting torque. A single phase induction motor requires a separate starting circuit to provide a rotating field to the motor. The normally operating windings within such a single-phase motor can cause the rotor to rotate in either direction, so the starting circuit determines the direction of operation.

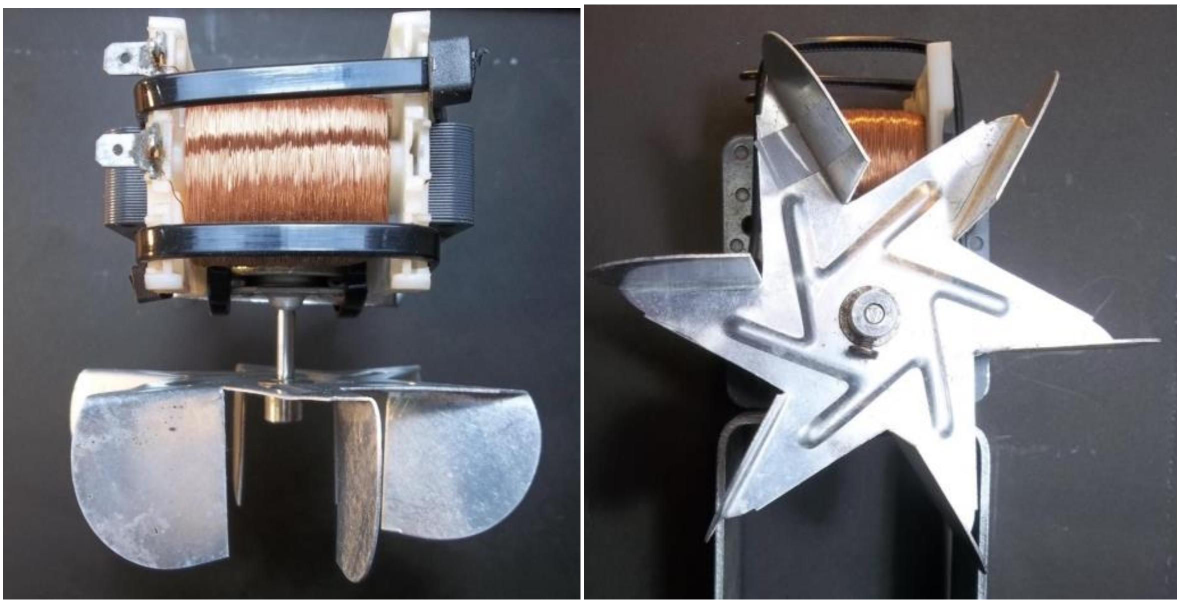
Because their starting torque is low, they are best suited for driving fans or other loads that start easily. Power above 250 (Watts) is not common and for larger motors, other designs offer better features. A main drawback is its low energy efficiency.

These single-phase asynchronous motors, in which the stator has a single-phase winding and the rotor is squirrel cage. They are small power motors and in them, by virtue of Leblanc's Theorem, the magnetic field is equal to the sum of two equal rotating fields that rotate in opposite directions. These single-phase motors do not start by themselves, so some auxiliary means must be provided for starting (which is the so-called "Frager loop").
Indeed, Leblanc's theorem says that a winding traveled by a single-phase alternating current creates a pulsating magnetic field, which is equivalent to two equal rotating magnetic fields that rotate in opposite directions that cancel each other out. A squirrel cage motor (such as a small shaded-pole motor) whose stator has a single winding through which a single-phase alternating current circulates cannot, according to Leblanc's theorem, start by itself.



Figures 6 and 7. On the left we see the magnetic flux in the shaded pole motor. A section of each pole is provided with a copper or bronze ring called "Frager's loop" (starting loop), where the induced currents retard the magnetic flux in their surroundings enough to provide an alternating field capable of providing a torque Boot. On the right we see the shaded-pole motor used in the experiment with 10,5 (mm) blades running at 1690 (RPM), a type of AC asynchronous single-phase induction motor. Source: self made.

On certain smaller single-phase motors, starting is done by a copper wire twisting around part of one pole; said pole is called “shaded pole”. These motors are typically used in applications such as desk fans, as the starting torque required is low and the low efficiency is tolerable relative to the reduced cost of the motor and starting method compared to other AC motor designs.



Figures 8 and 9. Shaded-pole motor, a type of AC asynchronous single-phase induction motor, used in the experiment, with 10.5 (mm) blades. Source: self made.

Table 1. The data of the shaded pole motor (Shaded-pole motor) or motor in short circuit (fragger's turn) calculated by formulas and data extracted by laboratory instruments (with the energy efficiency system "off") are detailed below in the following table with their respective formulas, values and physical units. Source: self made.

Denomination	**Formula**	**Worth**	**units**
active power	$\mathrm{P = V_{rms}.I_{rms}.Cos\ \emptyset}$	25	(W) : Watts
effective voltage	$\mathrm{V_{RMS} = \frac{V_{pico}}{\sqrt{2}}}$	224	(V) : Volts
effective current	$\mathrm{I_{RMS} = \frac{I_{pico}}{\sqrt{2}}}$	0,13	(A) : Amps
Power factor (cos phi)	$\mathrm{Cos\ \emptyset}$	0,86	(nls)
Reactive power	$\mathrm{Q = Sen\ \emptyset.\ \frac{P}{Cos\ \emptyset}}$	14,93	(VAr) : Volt-Amp Reactive
Apparent power	$\mathrm{S = V.I}$	29,12	(VA) : Volt-amps
Total impedance RL	$\mathrm{Z_{RL} = \frac{V_{RMS}}{I_{RMS}}}$	1,479	(kΩ) = kilohms
Endurance	$\mathrm{R = \frac{P}{{I_{RMS}}^2}}$	1479,2	(Ω)
inductive reactance	$\mathrm{X_L = \sqrt{Z^2 - R^2}}$	879,6	(mΩ) : milliohms
Angular frequency (pulsations)	$\omega = 2.\pi.f$	314,159	(Rad/S) : Radians/Seconds
Grid frequency	f	50	(Hz) : Hertz
Inductance	$\mathrm{L} = \frac{\mathrm{X_L}}{2.\pi.f}$	2,81	(H) : milliHenries
Phase shift between	Inductive circuit, the	0,03408 (º)	(º) : Degrees

total voltage and total current$(V_T)(I_T)$	voltage leads the current.	5,947 (Rads)	(Rad) : Radians
Impeller blade speed	$ns = \frac{120.f}{p}$	1690	(RPM) : Revolutions per minute

Table 2. The data of the shaded pole motor (Shaded-pole motor) or motor in short circuit (fragger's loop) calculated by formulas and data extracted by laboratory instruments (with the energy efficiency system "on") are detailed below in the following table with their respective formulas, values and physical units. Source: self made.

Denomination	**Formula**	**Worth**	**units**
active power	$\mathrm{P = V_{rms}.I_{rms}.Cos\ \emptyset}$	4	(W) : Watts
effective voltage	$\mathrm{V_{RMS}} = \frac{\mathrm{V_{pico}}}{\sqrt{2}}$	128	(V) : Volts
effective current	$\mathrm{I_{RMS}} = \frac{\mathrm{I_{pico}}}{\sqrt{2}}$	0,149	(A) : Amps
Power factor (cos phi)	$\mathrm{Cos\ \emptyset}$	0,21	(nls)
Reactive power	$\mathrm{Q = Sen\ \emptyset.}\ \frac{\mathrm{P}}{\mathrm{Cos\ \emptyset}}$	18,64	(VAr) : Volt-Amp Reactive
Apparent power	$\mathrm{S} = \sqrt{\mathrm{P^2 + Q^2}}$	19,072	(VA) : Volt-amps
Total impedance RL	$\mathrm{Z_{RL}} = \frac{\mathrm{V_{RMS}}}{\mathrm{I_{RMS}}}$		(Ω) = Ohms
Endurance	$\mathrm{R} = \frac{\mathrm{P}}{\mathrm{I_{RMS}}^2}$	180,1	(Ω)
inductive reactance	$\mathrm{X_L} = \sqrt{\mathrm{Z^2 - R^2}}$	838,8	(mΩ) : milliohms
capacitive reactance	$\mathrm{X_c} = \frac{1}{\mathrm{2.\pi.f.C}}$	1,06	(kΩ) : Kiloohms
total LC impedance	$\mathrm{Z_{LC} = 2.\pi.f.L} - \frac{1}{2.\pi.f.\mathrm{C}}$	1,06	(kΩ) : kilohms
Angular frequency (pulsations)	$\omega = 2.\pi.f$	314,159	(Rad/S) : Radians/Seconds
Grid frequency	f	50	(Hz) : Hertz
Inductance	$\mathrm{L} = \frac{\mathrm{X_L}}{2.\pi.f}$	2,67	(mH) : millihenry
capacitance	$\mathrm{C} = \frac{1}{\mathrm{\omega.X_c}}$	3	(: MicrofaradsμF)
Phase shift between total voltage and total current$(V_T)(I_T)$	Inductive circuit, the voltage leads the current.	(º) (Rad)	(º) : Degrees (Rad) : Radians
Impeller blade speed	$ns = \frac{120.f}{p}$	582	(RPM) : Revolutions per minute
resonant frequency	$f = \frac{1}{2\pi\sqrt{\mathrm{L.C}}}$	1,77	(kHz) : kilohertz

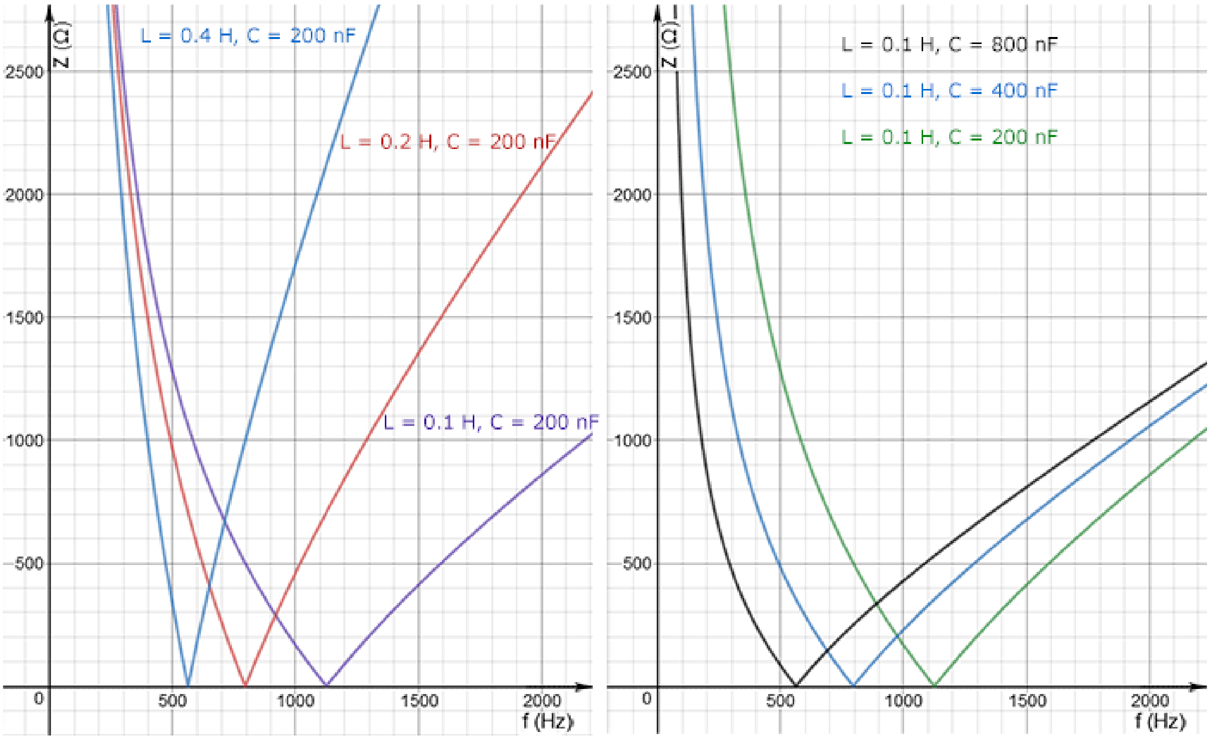


Figure 10. Various plots of ZLC series LC circuit impedance versus frequency f for a given inductance and capacitance show zero impedance at resonant frequencies. As the frequency increases, the reactance of the inductor increases and that of the capacitor decreases. However, if the frequency approaches zero (or direct current), the reactance of the inductor decreases to zero and that of the capacitor increases to infinity. At zero frequency, the series LC circuit acts as an open circuit. Notice that the impedance is inductive to the right of resonance, and capacitive to the left of it. Source: self made.

Motor wound in series (Series-Wound Motor) or universal asynchronous motor.
Universal motor is a type of electric motor that can run on either AC or DC power and uses an electromagnet as its stator to create its magnetic field. It is a commutated series-wound motor where the stator field coils are connected in series with the rotor windings through a commutator. It is often referred to as a series AC motor. The Universal Motor is very similar to a stock DC motor in construction, but is slightly modified to allow the motor to run properly on AC power. This type of electric motor can run well on AC because the current in both the field coils and the armature (and the resulting magnetic fields) will alternate (reverse polarity) synchronously with the supply. Therefore,
Universal motors have high starting torque, can run at high speed, and are lightweight and compact. They are commonly used in portable electrical tools and equipment, as well as many household appliances. They are also relatively easy to control, either electromechanically using tapped coils, or electronically. However, the commutator has brushes that do wear out, so they are used much less frequently for equipment that is in continuous use. Also, partly due to the commutator, universal motors tend to be very noisy, both acoustically and electromagnetically.

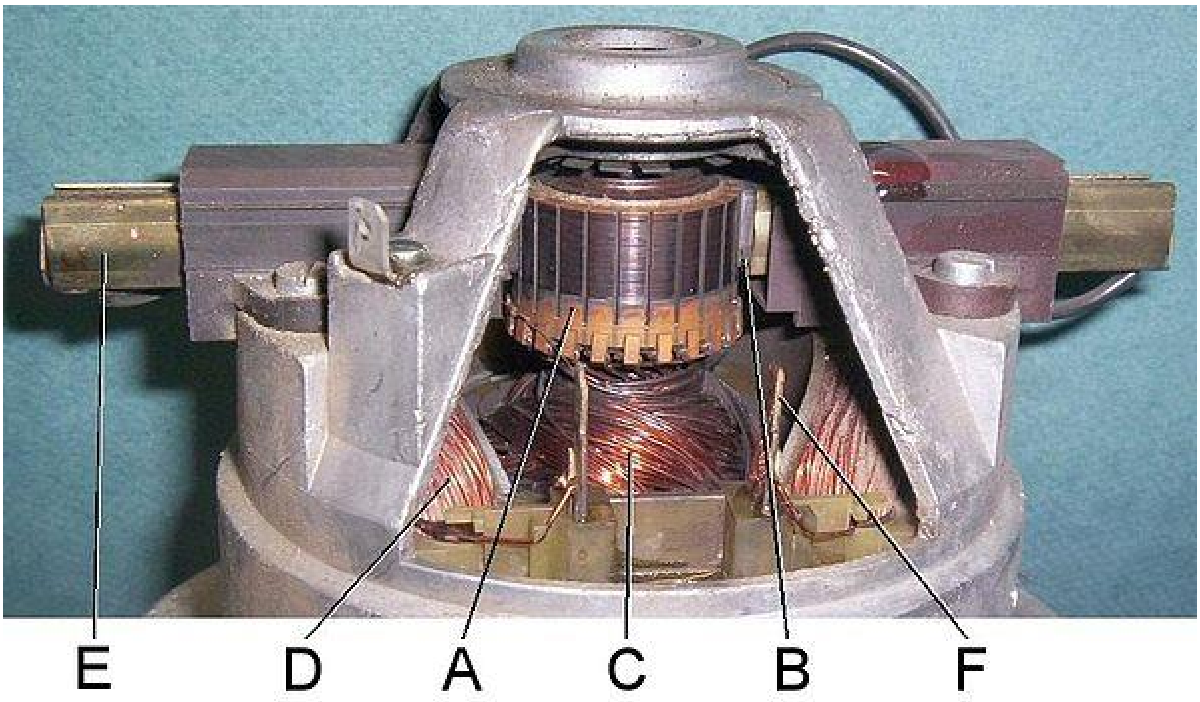


Figure 11. Commutated series-wound motor or universal AC-DC motor: (A) collector or commutator, (B) brush, (C) rotor winding, (D) stator coils (poles), (E) brush guide and (F) connections or terminals for power supply. Fountain:https://commons.wikimedia.org/wiki/File:Universal_motor_commutator.jpg

When the universal motor is connected to alternating current, its flux varies every half cycle. In the first half of the alternating current wave it is called positive, here the current in the armature windings has the same direction as clockwise, that is, from left to right, while the flow produced by the field winding has a direction from right to left, so the torque developed by the motor is counterclockwise.

In the second half of the alternating current wave, called negative, the applied voltage inverts its polarity, likewise the current changes its direction and is now from right to left, also the flow produced by the poles is now directed from left to right , the starting torque does not change its direction, since in the negative half both the direction of the current and that of the flux are reversed.

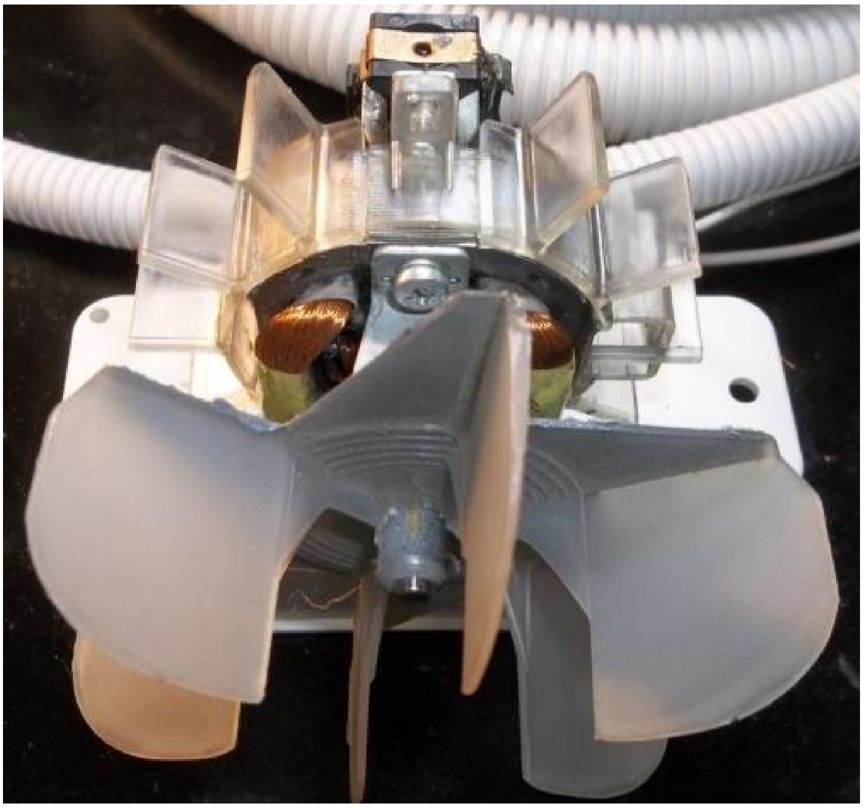
In this way it behaves in a similar way to a direct current series motor. As each time the direction of the current is reversed, it does so both in the inductor and in the armature, with which the motor torque retains its direction.

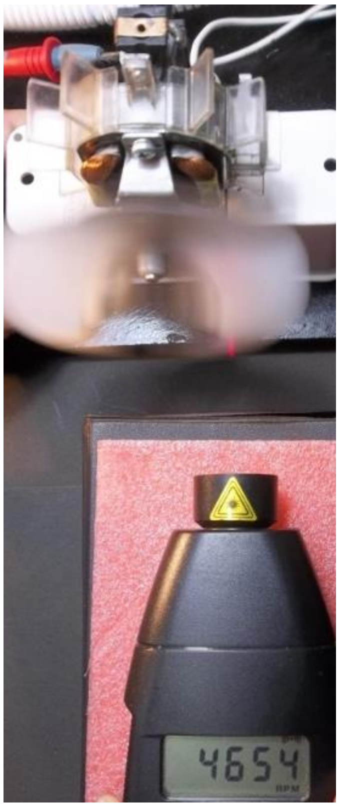
It has less power in alternating current than in direct current, because in alternating current the pair is pulsating. In addition, the current is limited by the impedance, formed by the inductor and the resistance of the winding. Therefore there will be a voltage drop due to reactance when it works with alternating current, which will result in a decrease in torque.

Increased sparking in the brushes when operating in alternating current, due to the fact that the armature coils are crossed by an alternating current when they are short-circuited by the brushes, which makes it necessary to put a compensating winding in medium-sized motors to counteract the electromotive force induced for that reason.

They are high-speed motors for light loads. The starting torque is also very large. Fraction horsepower series motors are used to drive fans, electric drills, and other small appliances.

The wound rotor motor has a rotor made up, instead of a cage, of a series of conductors wound on it in a series of slots located on its surface. In this way, there is a winding inside the stator's magnetic field, with the same number of poles, and in motion. This rotor is much more complicated to manufacture and maintain than the squirrel cage rotor, but it allows access to it from the outside through rings that short-circuit the windings. This has advantages, usually such as the possibility of using a starting resistor that allows the speed and starting torque to be modified, as well as reducing the starting current.





Figures 12 and 13. On the left is the series-wound motor (Series-Wound Motor) or universal asynchronous motor stopped with 10,5 (mm) blades and on the right running at 4654 (RPM). Source: self made.

Table 3. The data of the series-wound motor (Series-Wound Motor) or universal asynchronous motor calculated by formulas and data extracted by laboratory instruments (with the energy efficiency system "off") are detailed below in the following table with their respective formulas, values and physical units. Source: self made.

Denomination	**Formula**	**Worth**	**units**
active power	$P = V_{rms}.I_{rms}.\text{Cos}\,\emptyset$	242	(W) : Watts
effective voltage	$V_{RMS} = \frac{V_{pico}}{\sqrt{2}}$	225	(V) : Volts
effective current	$I_{RMS} = \frac{I_{pico}}{\sqrt{2}}$	1,1	(B) : Amps
Power factor (cos phi)	$\text{Cos}\,\emptyset$	0,98	(nls)
Reactive power	$Q = \text{Sen}\,\emptyset.\ \frac{P}{\text{Cos}\,\emptyset}$	51,8	(VAr) : Volt-Amp Reactive
Apparent power	$S = V.I$	247,5	(VA) : Volt-amps
Total impedance RL	$Z_{RL} = \frac{V_{RMS}}{I_{RMS}}$	200	(Ω) = Ohms

Endurance	$R = \frac{P}{I_{RMS}{}^2}$	200	(Ω)
inductive reactance	$X_L = \sqrt{Z^2 - R^2}$	713,99	(mΩ) : milliohms
Angular frequency (pulsations)	$\omega = 2.\pi.f$	314,159	(Rad/S) : Radians/Seconds
Grid frequency	f	50	(Hz) : Hertz
Inductance	$L = \frac{X_L}{2.\pi.f}$	2.27	(mH) : milliHenries
Phase shift between total voltage and total current$(V_T)(I_T)$	Inductive circuit, the voltage leads the current.	0,20454 (º) 0,00357 (Rad)	(º) : Degrees (Rad) : Radians
Impeller blade speed	$ns = \frac{120.f}{p}$	4654	(RPM) : Revolutions per minute

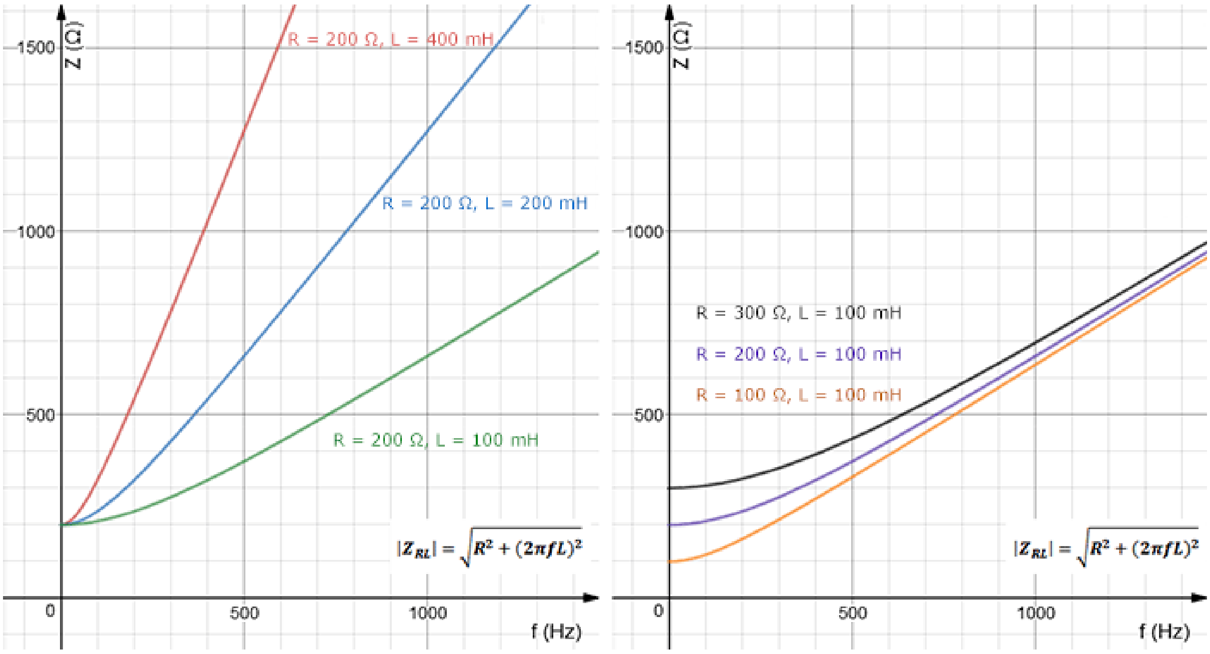


Figure 14. A plot of the ZRL impedance of the series RL circuit against the frequency f for a given inductance and resistance. Source: self made.

Table 4. The data of the series-wound motor (Series-Wound Motor) or universal asynchronous motor calculated by formulas and data extracted by laboratory instruments (with the energy efficiency system "on") are detailed below in the following table with their respective formulas, values and physical units. Source: self made.

Denomination	Formula	Worth	units
active power	$P = V_{rms}.I_{rms}.\text{Cos } \emptyset$	25	(W) : Watts
effective voltage	$V_{RMS} = \frac{V_{pico}}{\sqrt{2}}$	91	(V) : Volts
effective current	$I_{RMS} = \frac{I_{pico}}{\sqrt{2}}$	0,42	(B) : Amps
Power factor (cos phi)	$\text{Cos } \emptyset$	0,67	(nls)

Reactive power	$Q = \text{Sen } \emptyset. \dfrac{P}{\text{Cos } \emptyset}$	28,91	(VAr) : Volt-Amp Reactive
Apparent power	$S = \sqrt{P^2 + Q^2}$	38,22	(VA) : Volt-amps
Total impedance RL	$Z_{RL} = \dfrac{V_{RMS}}{I_{RMS}}$	216,66	(Ω) = Ohms
Endurance	$R = \dfrac{P}{{I_{RMS}}^2}$	141,72	(Ω)
inductive reactance	$X_L = \sqrt{Z^2 - R^2}$	163,86	(Ω) : Ohms
capacitive reactance	$X_c = \dfrac{1}{2.\pi.f.C}$	1,06	(kΩ) : Kilohms
total LC impedance	$Z_{LC} = 2.\pi.f.L - \dfrac{1}{2.\pi.f.C}$	193,78	(Ω)
Angular frequency (pulsations)	$\omega = 2.\pi.f$	314,159	(Rad/S) : Radians/Seconds
Grid frequency	f	50	(Hz) : Hertz
Inductance	$L = \dfrac{X_L}{2.\pi.f}$	0.5216	(H) : Henrys
capacitance	$C = \dfrac{1}{\omega.X_c}$	3	(: MicrofaradsμF)
Phase shift between total voltage and total current$(V_T)(I_T)$	Inductive circuit, the voltage leads the current.	90 (º) 1.5708 (Rads)	(º) : Degrees (Rad) : Radians
Impeller blade speed	$ns = \dfrac{120.f}{p}$	2103	(RPM) : Revolutions per minute
resonant frequency	$f = \dfrac{1}{2\pi\sqrt{L.C}}$	127,23	(Hz) :Hertz

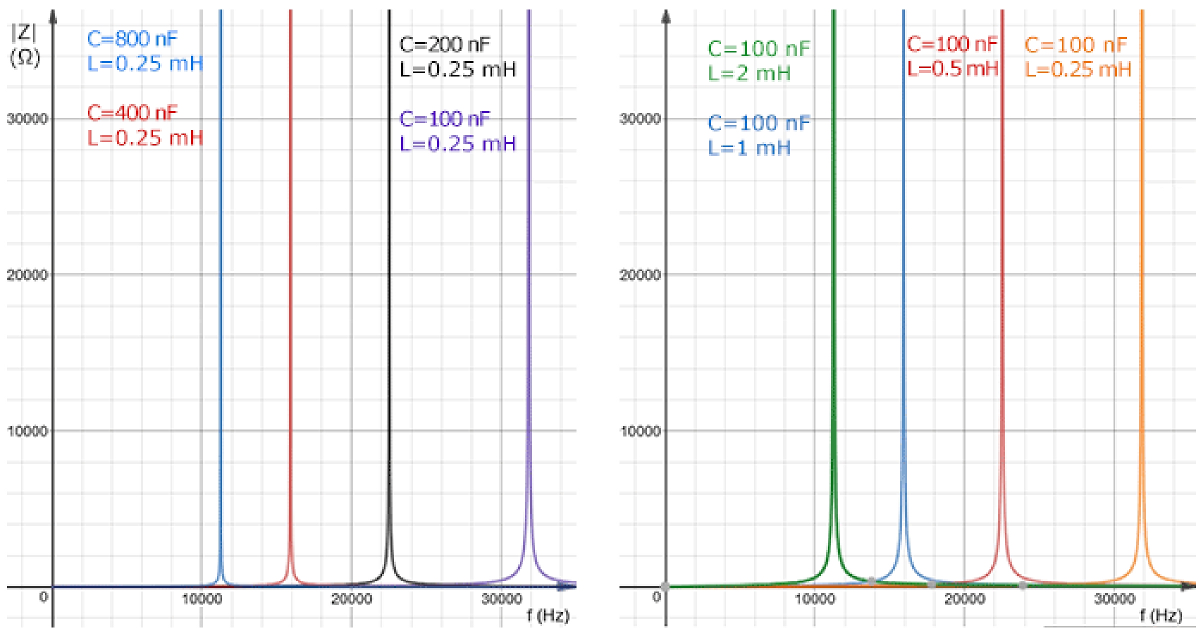
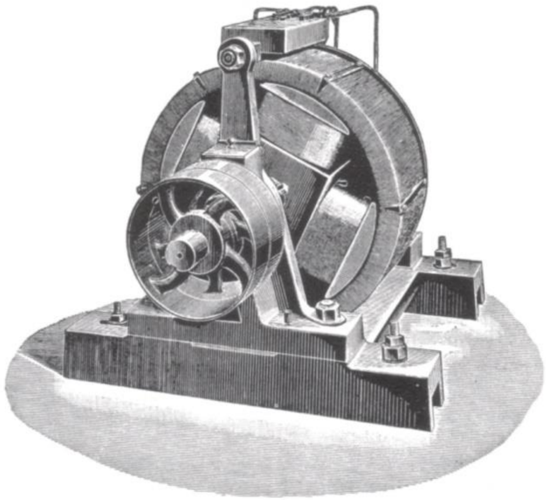


Figure 15. A plot of ZLC impedance against frequency f of several parallel LC circuits for a given inductance and capacitance shows infinitely large impedance at resonant frequencies.Source: self made.

Permanent magnet synchronous motor (Syncrhonous Motor-Permanent Magnet).
Synchronous motors are a type of alternating current motor in which the rotation of the shaft is directly related to the frequency of the supply current 50 (Hertz); the speed of rotation of the shaft is exactly equal to the synchronous speed of the rotating magnetic field of the stator. Its turning speed is constant and depends on the frequency of the voltage of the electrical network to which it is connected and the number of pairs of motor poles, this speed being known as "synchronous speed". This type of motor can contain electromagnets or permanent magnets in the rotor (depending on the type of synchronous motor in question) that create a magnetic field that rotates over time at the synchronous speed established by the stator magnetic field.
Historically, Friedrich August Haselwander's three-phase synchronous machine is recognized as one of the first inventions. In order to establish electricity, a way was needed to transmit power with as little loss as possible. This low-loss transmission is directly related to the voltage level: the higher the voltage, the lower the losses. Haselwander addressed this problem early on. His first such generator came online in October 1887. He seamlessly integrated his invention into existing DC and AC systems. The patent application filed in July 1887 and in 1889, however, the patent was granted.
In 1891 Haselwander was able to show his generator with a three-phase stationary ring armature and a four-pole rotor, as shown in the adjacent illustration, at the 1891 International Electrotechnical Exhibition in Frankfurt. But the prototype remained, which he then gave to the Deutsches Museum in Munich while he was still alive, where the system still stands today.



Dr. ing. h. c. Friedrich Aug. Haselwanders Drehstrom-Maschine

Figure 16. The first three-phase synchronous generator with salient poles. Fountain:https://commons.wikimedia.org/wiki/File:Drehstrommaschine.jpg

Although the image above is that of a synchronous generator, the synchronous machine is a reversible machine since it can be used as an alternating current generator or as a synchronous motor.

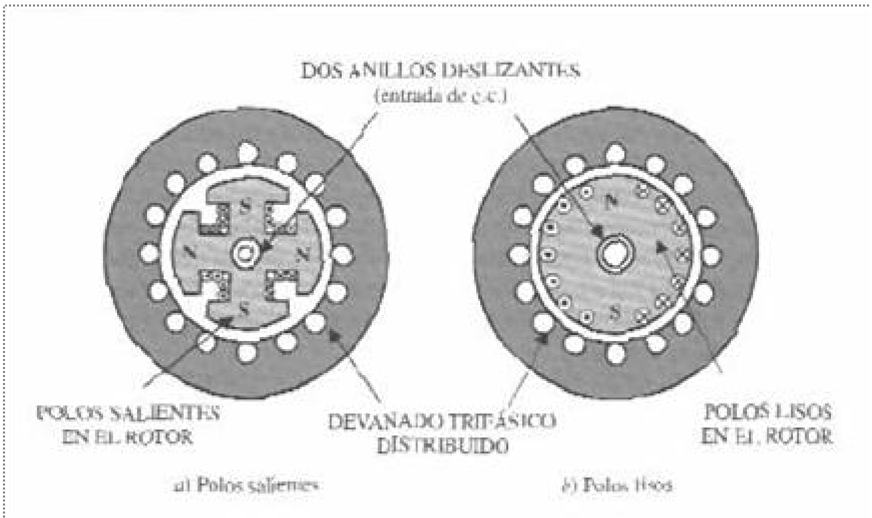


Figure 17. Construction types of synchronous machines: (a) on the left "protruding poles" on the rotor and (b) on the right "smooth poles" on the rotor. Fountain: https://selectromecanicosu.wixsite.com/seuv/quienes-somos1

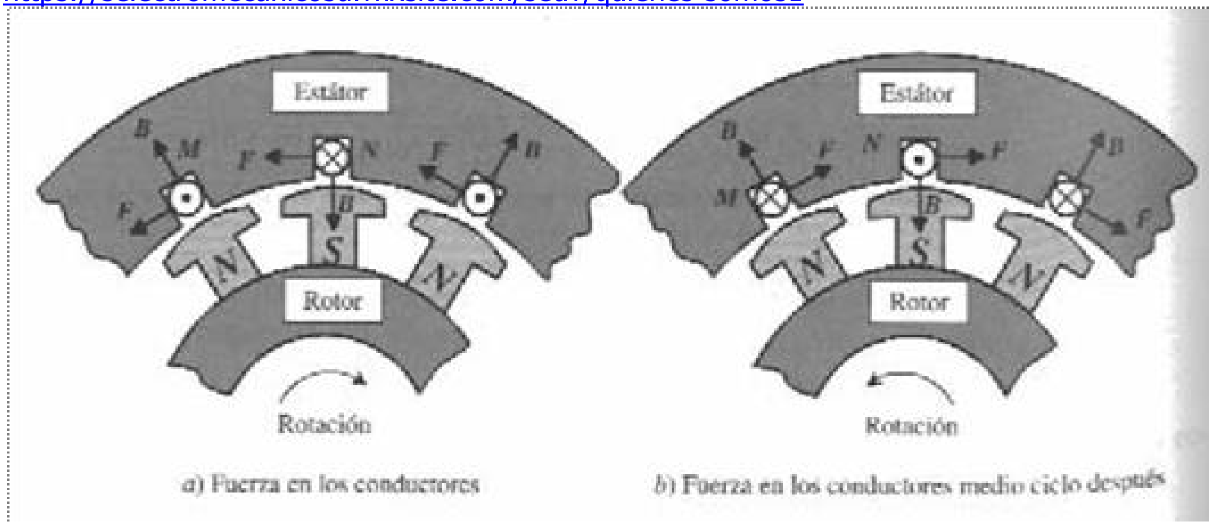


Figure 18. Principle of operation of the synchronous motor. Fountain: https://selectromecanicosu.wixsite.com/seuv/quienes-somos1

Consider a single-phase generator like the one in the following figure. The generator rotor consists of a permanent magnet (ferrite or neodymium) that generates a magnetic field B (1 Tesla = 10,000 Gauss) or constant magnetic induction vector and is rotating (thanks to an external driving machine) at an angular speed (ω), if we measure the voltage e(t) the sinusoidal curve shown on the right of the figure is observed.

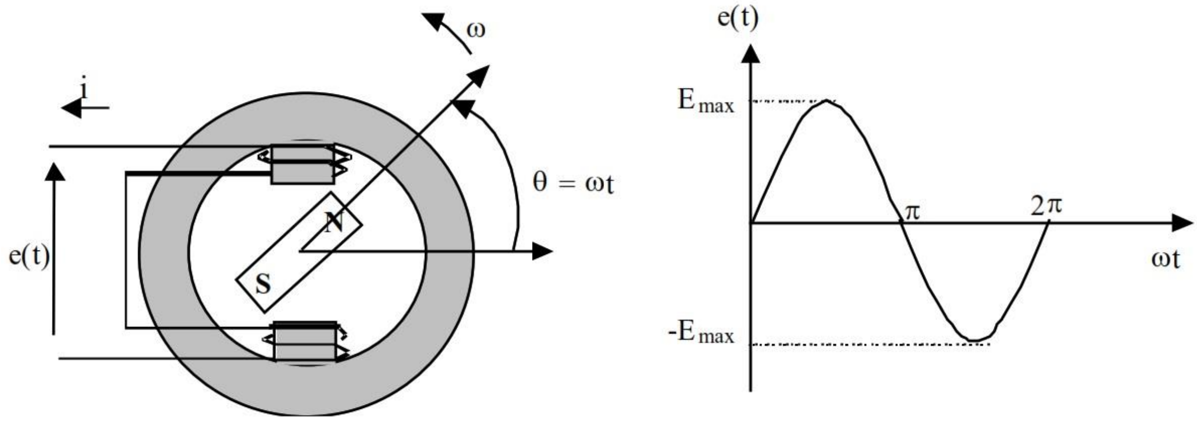


Figure 19. Generator uncoupled from the grid. Fountain:https://commons.wikimedia.org/wiki/File:Drehstrommaschine.jpg

The rotation of the rotor axis causes the flux linked by the stator coil to be variable so that the voltage generated at its terminals is due to the temporary variation of said flux, which is known as the Lenz-Faraday Law:

$$e = -N\frac{d\Phi}{dt}$$

Faraday's Law states that any change in the magnetic environment of a coil of wire will cause a voltage (emf) to be "induced" in the coil. No matter how the change occurs, the voltage will be generated. The change could be brought about by changing the strength of the magnetic field, moving a magnet toward or away from the coil, moving the coil into or out of the magnetic field, rotating the coil relative to the magnet, etc. The sense of the induced emf is given by Lenz's Law.

The magnetic flux (represented by the Greek letter fi: Φ) has the form:

$$\Phi = B.A.\cos(\omega t)$$

The induced voltage is:

$$e(t) = k.B.\omega.sen(\omega t) = E_{max}.sen(\omega t)$$

Where:
what, is a design constant of the machine (it depends on the area of the section "A", the number of turns "N" and in general the geometry of the winding).
B, is the magnetic field generated by the rotor.
ω, is the mechanical speed of the rotor.

In the same way, other formulas to calculate the maximum voltage generated from the area (A) and the number of turns (N) of the copper winding (winding) of the stator with a magnetic field generated by permanent magnets of ferrite or neodymium is:

$$E_{max} = \omega.N.B.A$$

Being:
ω,angular velocity (radians/seconds).
N, number of turns.
B, magnetic field (Tesla).
A, área (meters^2)

Since the generator is a reversible machine since it can be used as an alternating current generator or as a synchronous motor, when connected to the 220 (Volts) and 50 (Hz) electrical, home or commercial network. The speed of rotation of the axis is imposed by the network and the mathematical expression that relates the speed of the machine with the mentioned parameters is:

$$n = \frac{120.f}{p}$$

where:
f: Frequency of the network to which the machine is connected (Hz)
p: Number of poles that the machine has
n: Machine synchronous speed (revolutions per minute)

Like the asynchronous induction machine, the stator of the synchronous machine is powered by alternating currents. This causes a rotating magnetic field to be produced which induces a magnetomotive force in the three-phase stator windings given by the following equation:

$$F_e = \frac{3}{2}.F_m.cos(\omega t - \Theta)$$

Where:
F_e, is the magnetomotive force of the stator.
F_m, is the maximum force equivalent to N.I_{max} ("N" the number of turns of the stator coil and the "I_{max}" maximum value of the supply current).
ω, is the synchronous speed.
Θ, is the angle that determines the position of the air gap point where the magnetomotive force is being calculated.

A three-phase power supply provides a rotating magnetic field in a synchronous motor in the same way as it does in an asynchronous induction motor (no difference).
The clarification of the previous equation on a three-phase stator is because the consulted bibliography does not refer to single-phase synchronous stators, although their experimental behaviors are analogous. Industrial power requirements make it necessary for motors to be supplied with three-phase voltages.
The previous expression implies that the maximum of the magnetomotive force, when cos $(\omega t - \Theta)$=0, moves through the air gap at the speed Θ=, that is, at the synchronous speed. This synchronous speed corresponds to the network frequency.
In the case of the synchronous machine rotor, which is powered by permanent magnets (ferrite) which makes the magnetomotive force constant and is fixed to it. Under these conditions, the rotating magnetic field of the rotor tends to align with the rotating magnetic field of the stator causing the shaft to rotate at synchronous speed.
The expression of the instantaneous torque of the machine is given by the following formula:

$$T(t) = K_T.F_e.F_{r.}sen\ \delta$$

Where:
K_T, is a design constant of the machine.
F_e, is the magnetomotive force of the stator.
F_r, is the magnetomotive force of the rotor.
δ, delta is the angle between the magnetomotive forces of the stator and rotor.

It is feasible to verify that the existence of an average torque is subject to the condition that the angle between the magnetomotive forces (δ=delta) is constant, which is true since both magnetic fields rotate at synchronous speed.
In accordance with the above, in the case of the synchronous motor, the characteristic, torque speed is the one shown in the following figure.

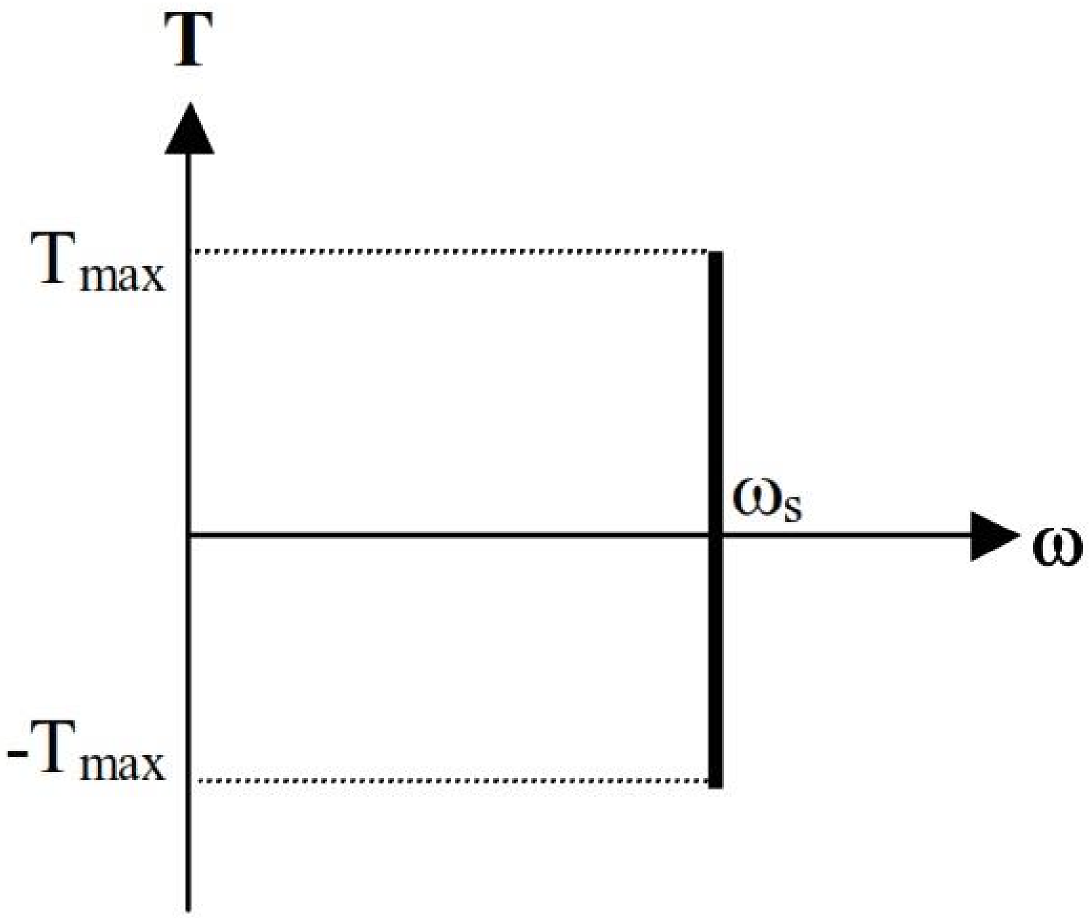


Figure 20. Torque speed characteristic of the synchronous motor. Fountain:https://commons.wikimedia.org/wiki/File:Drehstrommaschine.jpg

$$\omega_s = 2.\pi.\frac{f}{P}$$

Where:
ω_s, synchronous speed, in this case: 314.159 (radians/seconds).
f, network frequency, in this case: 50 (Hertz).
P, number of pairs of rotor poles, in this case: P=1.

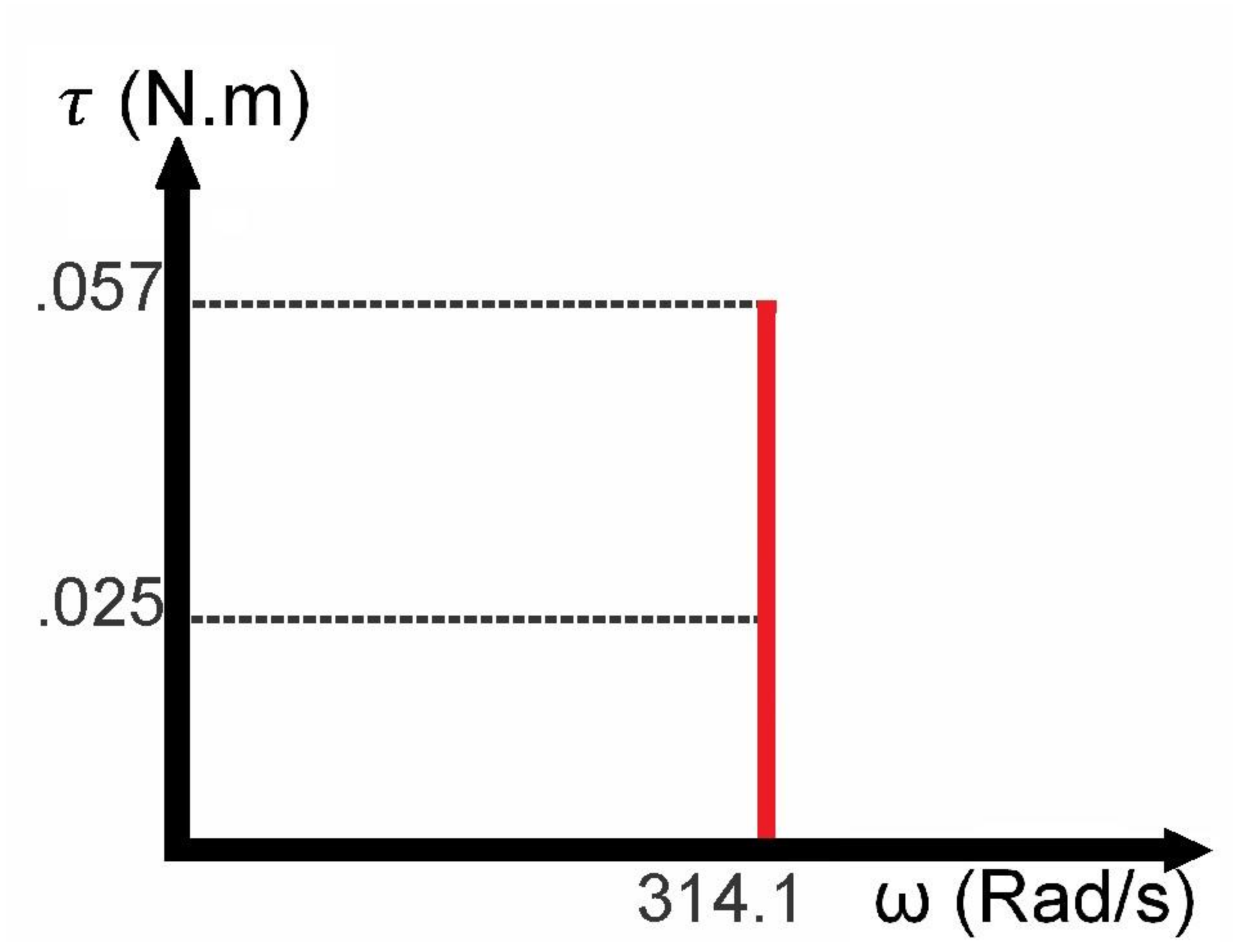


Figure 21. Graph of the torque-speed curve, where the synchronous speed ω=313.159 (Rad/s) of the rotor as a function of the minimum torque of τ=0.025 (N.m) and the maximum torque of τ=0.057 (N.m). Remembering that the rotation speed of a synchronous motor is directly proportional to the frequency of the network in which it is connected of 50 (Hz). Being: 314.159 (Rad/s)=3000 (RPM). Source: self made.

From the figure it can be seen that the motor does not have starting torque, therefore it requires additional mechanisms that allow starting until it reaches synchronous speed.
Above a certain size, synchronous motors are not self-starting motors. This property is due to the inertia of the rotor; it cannot instantaneously follow the rotation of the stator's magnetic field. Since a synchronous motor does not produce an inherent average torque at rest, it cannot accelerate to synchronous speed without some complementary mechanism.
Large motors running on a commercial power frequency include a squirrel cage induction winding that provides sufficient torque for acceleration and also serves to damp oscillations in running motor speed. Once the rotor approaches synchronous speed, the field winding is energized and the motor is synchronized. Very large motor systems may include a so-called "pony" motor (or starting aid) that accelerates the unloaded synchronous machine before the load is applied. Electronically controlled motors can be accelerated from zero speed by changing the frequency of the stator current with a Variable Frequency Drive (VDF).
We can identify starting problems and torque limitations by saying that single-phase synchronous motors can rotate freely in any direction, unlike the shaded-pole type, which provides a uniform starting direction; but this design will only work satisfactorily if the rest charge is close to zero and has very little inertia (as in the hands of a clock). Even by

shaded pole motor standards, the power output of these motors is usually very low. Therefore, it is difficult to have a starting torque to overcome the stationary inertia of the stopped rotor blades and make them accelerate at the speed of the rotation frequency of the mains supply. Because there is often no explicit starting mechanism, the rotor of a motor running on a constant frequency power supply must be very light so that it can reach operating speed within one cycle of the mains frequency.

Within the family of synchronous motors we must distinguish:

There are basically three types of synchronous motors: (a) Reluctance motors, (b) Hysteresis motors and (c) Permanent-Magnet Motors. We are particularly interested in the PMSM/IPM type motor (Permanent Magnet Synchronous Motor/Interior Permanent Magnet) or synchronous motor with permanent magnets (ferrite or neodymium) or with permanent magnets inside the rotor.

A permanent magnet synchronous motor (PMSM) uses permanent magnets embedded in the steel rotor to create a constant magnetic field. The stator has windings connected to an AC supply to produce a rotating magnetic field (as in an asynchronous motor). At synchronous speed, the rotor poles are locked in the rotating magnetic field. Permanent magnet synchronous motors are similar to brushless DC motors. Neodymium magnets are the most commonly used magnets in these motors. Although in recent years, due to the rapid fluctuation in the prices of 14000 (Gauss) Neodymium (Nd2Fe14B) magnets, many researches have been looking for an alternative in 4000 (Gauss) ferrite magnets. Due to the inherent characteristics of currently available ferrite magnets, the magnetic circuit design of these machines needs to be able to concentrate the magnetic flux, one of the most common strategies is the use of radial type rotors. Today, newer machines using ferrite magnets have lower power density and torque density than machines using neodymium magnets (but are less expensive).

A permanent magnet synchronous motor (PMSM) uses permanent magnets embedded in the steel rotor to create a constant magnetic field. The stator has windings connected to an AC supply to produce a rotating magnetic field (as in an asynchronous motor). At synchronous speed, the rotor poles are locked in the rotating magnetic field.

Most PMSMs require a Variable Frequency Drive (VDF) to get started. However, some incorporate a "squirrel cage" rotor for starting; these are known as online-booting or auto-booting PMSMs. They are typically used as higher-efficiency replacements for induction motors (due to the lack of slip), but must be carefully specified for the application to ensure synchronous speed is achieved and the system can withstand torque ripple. during starting.

Permanent magnet synchronous motors are mainly controlled by "direct torque control" and "field oriented control". However, these methods suffer from relatively high torque and stator flux waves, additionally require the use of Variable Frequency Drives (VFDs) which require complex and expensive electronics. The use of VDF associated with PMSM motors makes the process of using this type of motor much more complex and expensive (considering if they are neodymium magnets). Costs increase and become less competitive compared to other types of technologies.

Figure 22. A variable frequency drive (VFD acronym: Variable Frequency Drive or AFD Adjustable Frequency Drive) is a system for controlling the rotational speed of an alternating current (AC) motor by means of frequency control power supplied to the motor. A variable frequency drive is a special case of a variable speed drive. Variable frequency drives are also known as adjustable frequency drives (AFDs), AC drives, or microdrives. Since the voltage (or voltage) is made to vary at the same time as the frequency, they are sometimes called VVVF (Variable Frequency Variable Voltage) drivers. Fountain: https://commons.wikimedia.org/wiki/File:Small_variable-frequency_drive.jpg

It is not the objective of this paper to specify what a VDF consists of, only to cite it to take it into account, that with this work it has been possible to eliminate it. Reducing costs and increasing competitiveness.

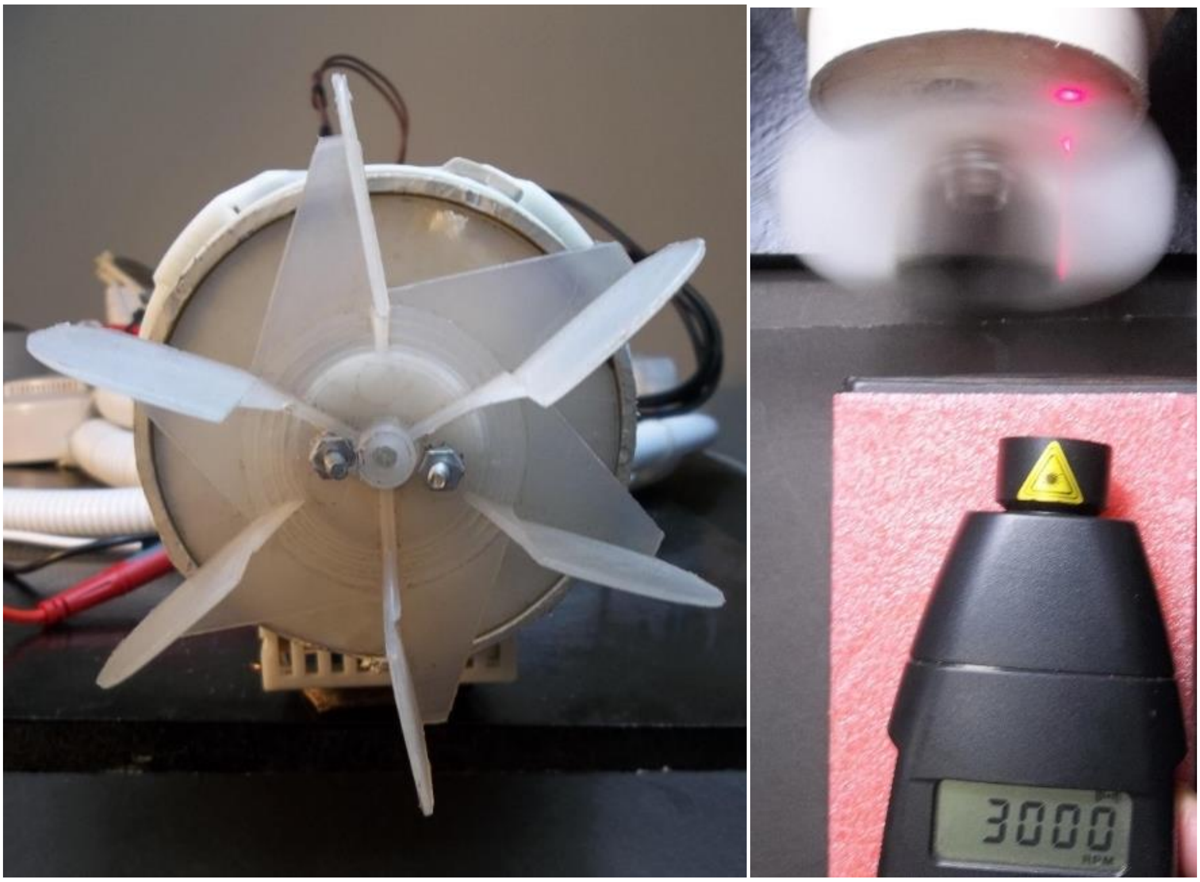


Figure 23. Left PMSM-type synchronous motor stopped with 10.5 (mm) blades. On the right the same motor turning at 3000 (RPM). Source: self made.

Methodology and bibliographic analysis.

(A) Simulation by NI Multisim 14.0 software [34].

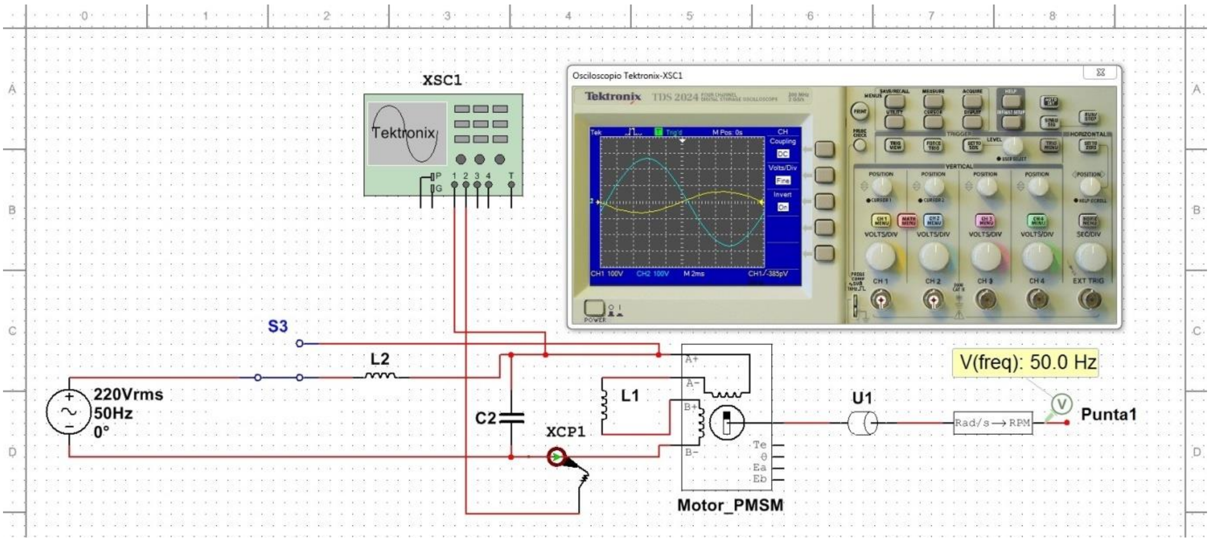


Figure 24. With the SPDT switch off, the THDv (in voltage) is 20.5%, and it has a THD greater than 5%, which is not acceptable by the IEEE 519 standard. Voltage and current are

observed on the oscilloscope. Source: self made. With the SPDT switch connected to the RCL circuit, the inductive-capacitive type low-pass circuit design that works analogously to a resistive-capacitive one has a THDv (voltage) less than 5%, which is acceptable per IEEE 519 standard The harmonics in the oscilloscope are reduced, in the voltage waveform. Source: self made.

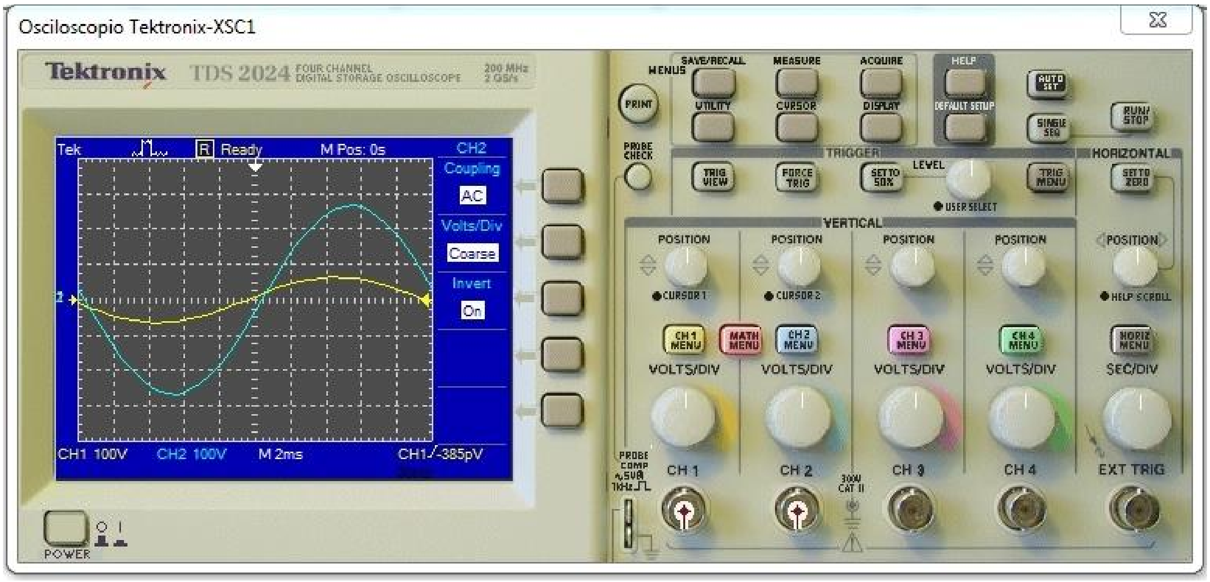


Figure 25. What is important is what happens in both cases -figures 10 and 11- in the probe (Point 1) that records the detail of the analyzer tip, converting radians over seconds to revolutions per minute (Rad/s to RPM) and these in frequency (Hertz), on the mechanical work done by the rotor on the centrifugal radial blades (load). It is observed that it rotates at 3000 (RPM) which is equivalent to 50 (Hz), product of the frequency of the synchronous motor. Regardless of whether the SPDT switch is "off" or "on" in Energy Efficiency (EE) mode; since in both cases, the frequency of the alternating current is always 50 (Hertz). For this reason, the motor, although its torque decreases, does not decrease its speed. Source: self made.

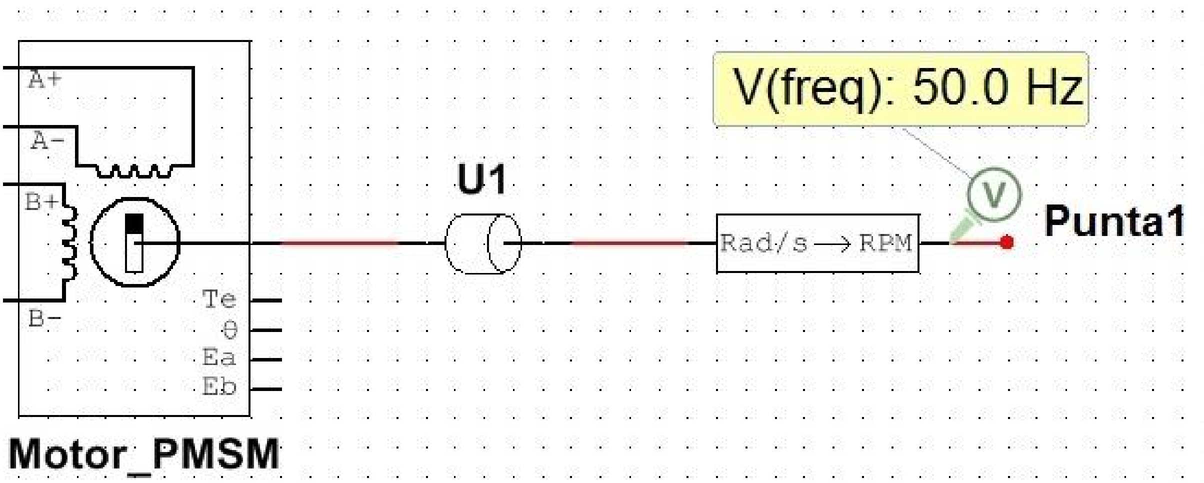


Figure 26. Enlargement of the detail of the analyzer tip that converts revolutions per minute (RPM) to frequency (Hertz), on the mechanical work done by the motor (from the frequency of the synchronous motor, fed with the single-phase power supply of 220 (VAC) and 50

(Hz).Without losing speed in the rotation of the rotor shaft, that is, without reducing the ability to perform mechanical work on the radial blades.Source: own elaboration.represented by the charge symbol: U5) . It is observed that it rotates at 3000 (RPM) which is equivalent to 50 (Hz). Source: self made.

(B) CFTurbo 2.0 software simulation:

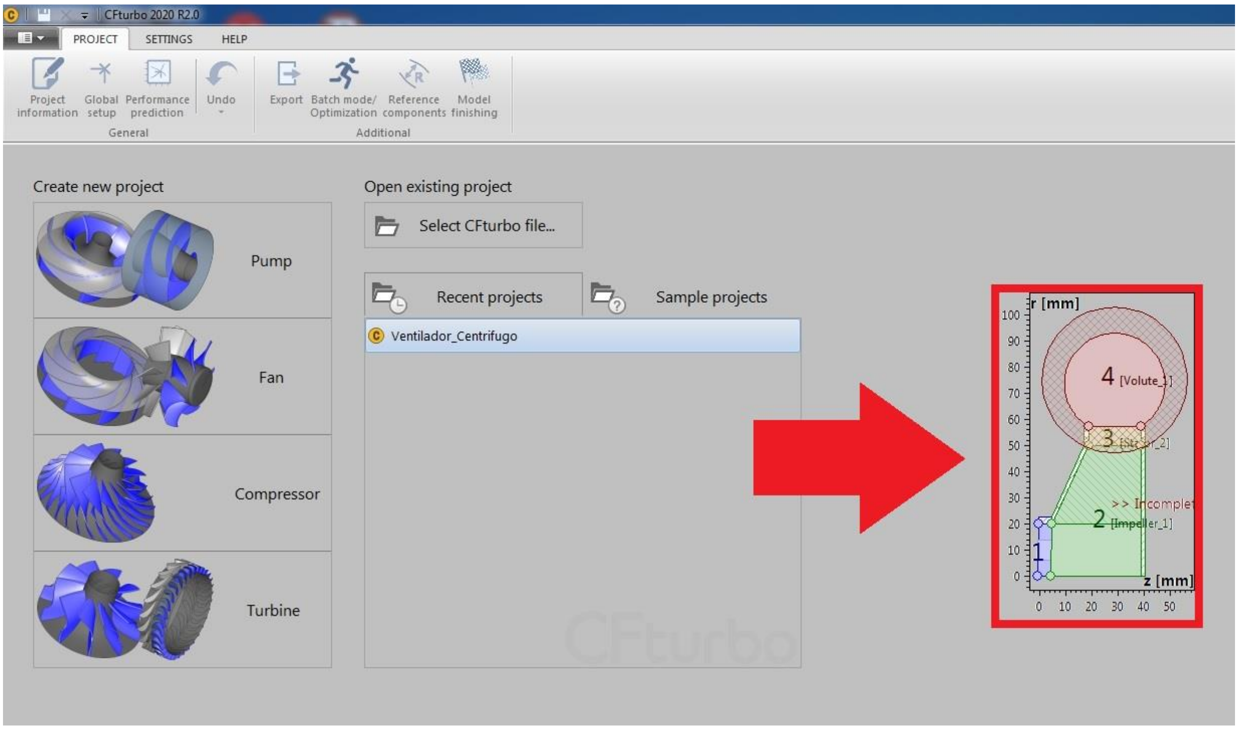


Figure 27. CFturbo 2020 R2.0 software. Development of the centrifugal fan (fan). Opening of files, under license: https://www.cfturbo.com Source: self made.

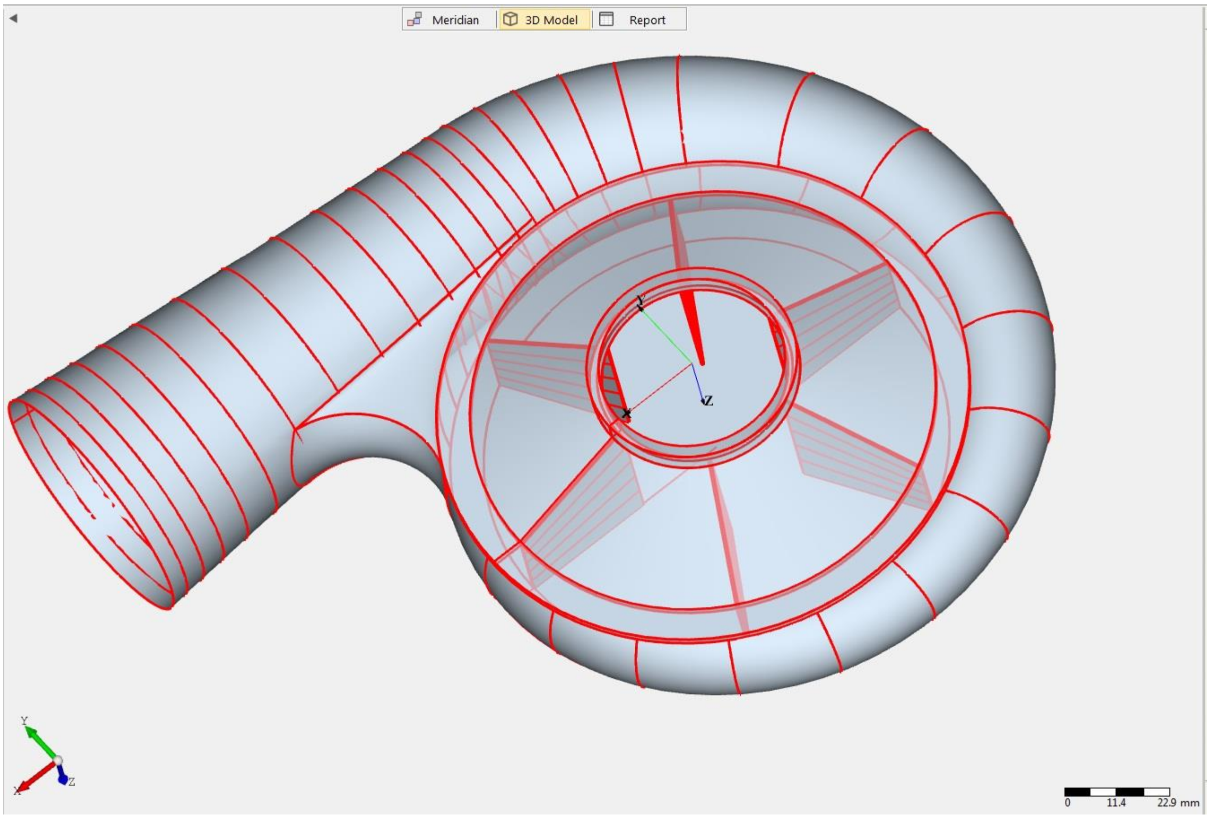


Figure 28. CFturbo 2020 R2.0 software. Selection in 3D modeling of stator, impeller and volute. Source: self made.

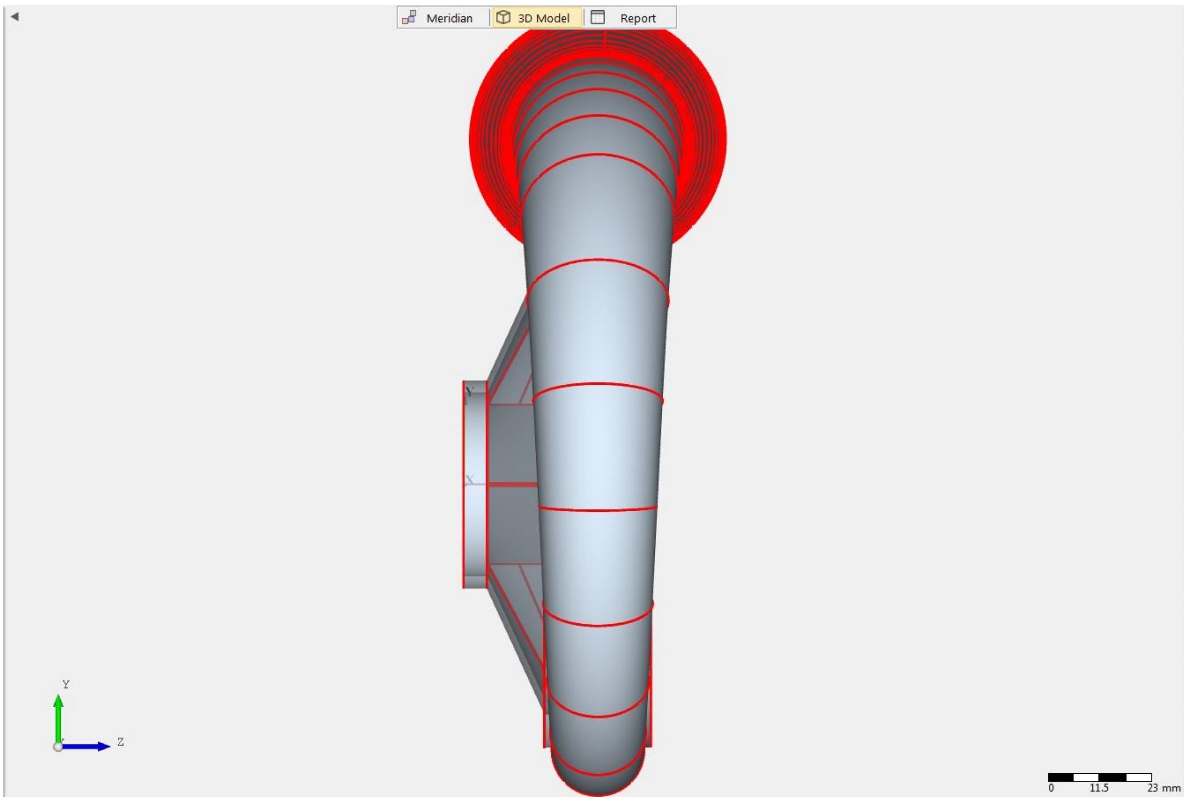


Figure 29. CFturbo 2020 R2.0 Software. Selection in 3D modeling, X axis. Source: Own elaboration.

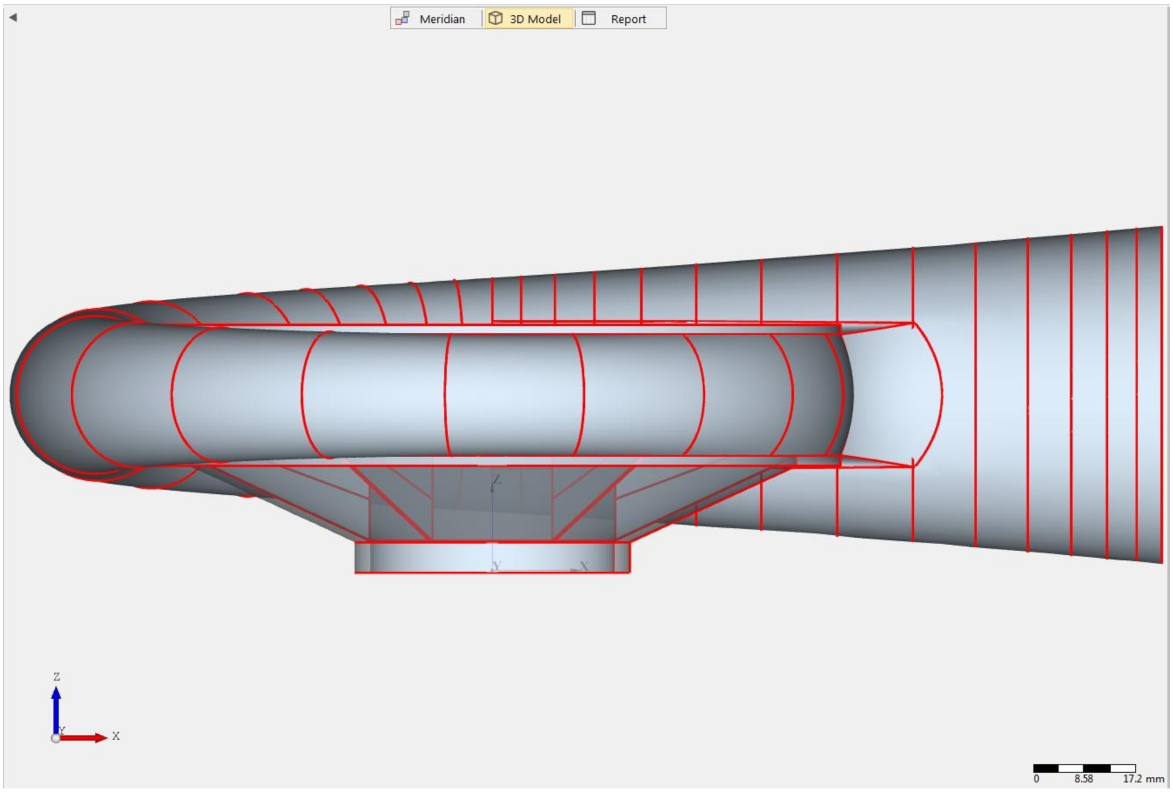


Figure 30. CFturbo 2020 R2.0 Software. Selection in 3D modeling, Y axis. Source: Own elaboration.

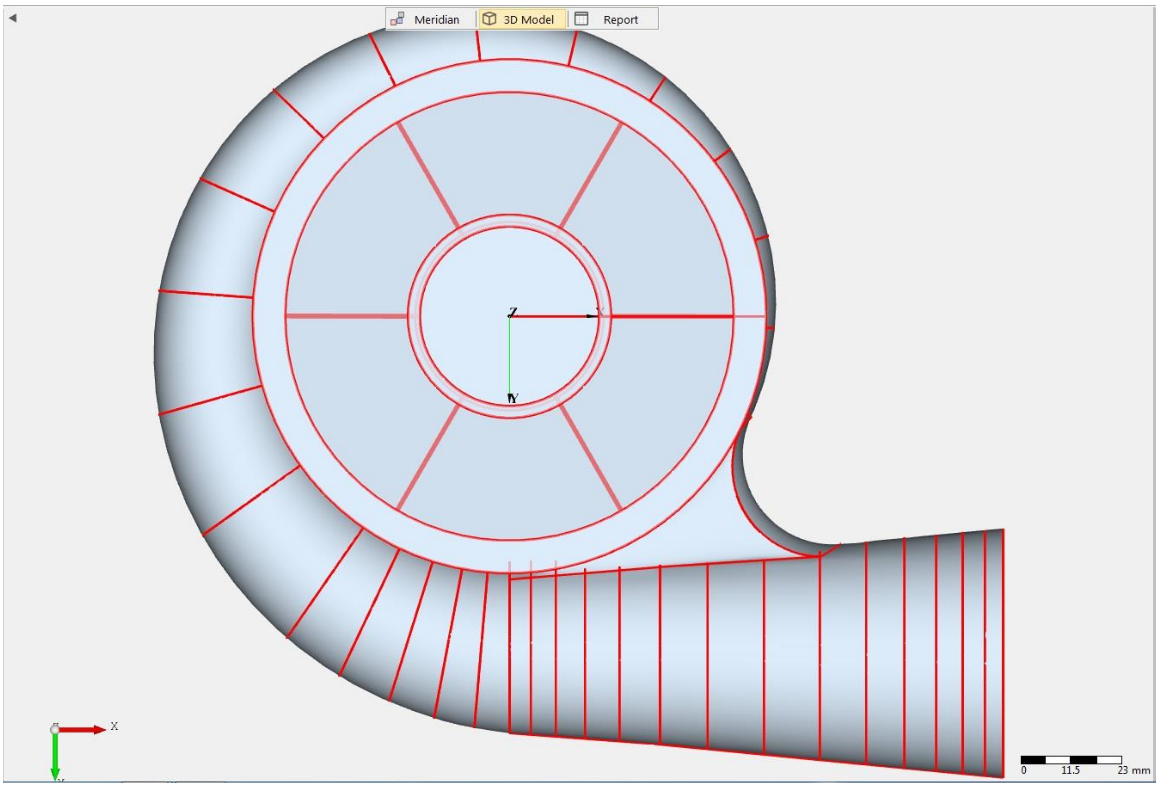


Figure 31. CFturbo 2020 R2.0 software. Selection in 3D modeling, Z axis. Source: Own elaboration.

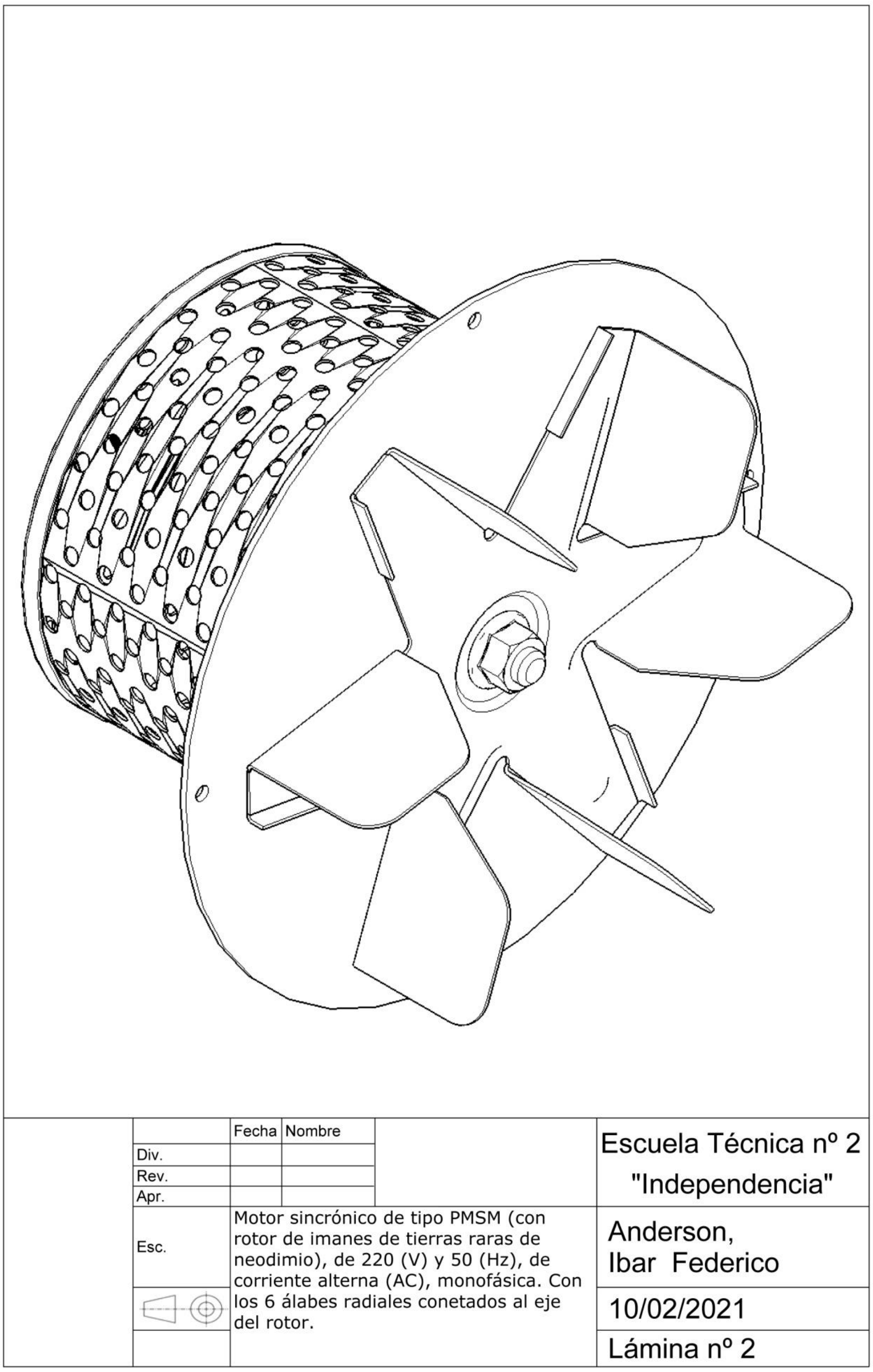


Figure 32. Isometric perspective of the PMSM/IPM 220 (V) and 50 (Hz) single-phase alternating current (AC) synchronous motor, with the six radial blades connected to the rotor shaft. Source: self made.

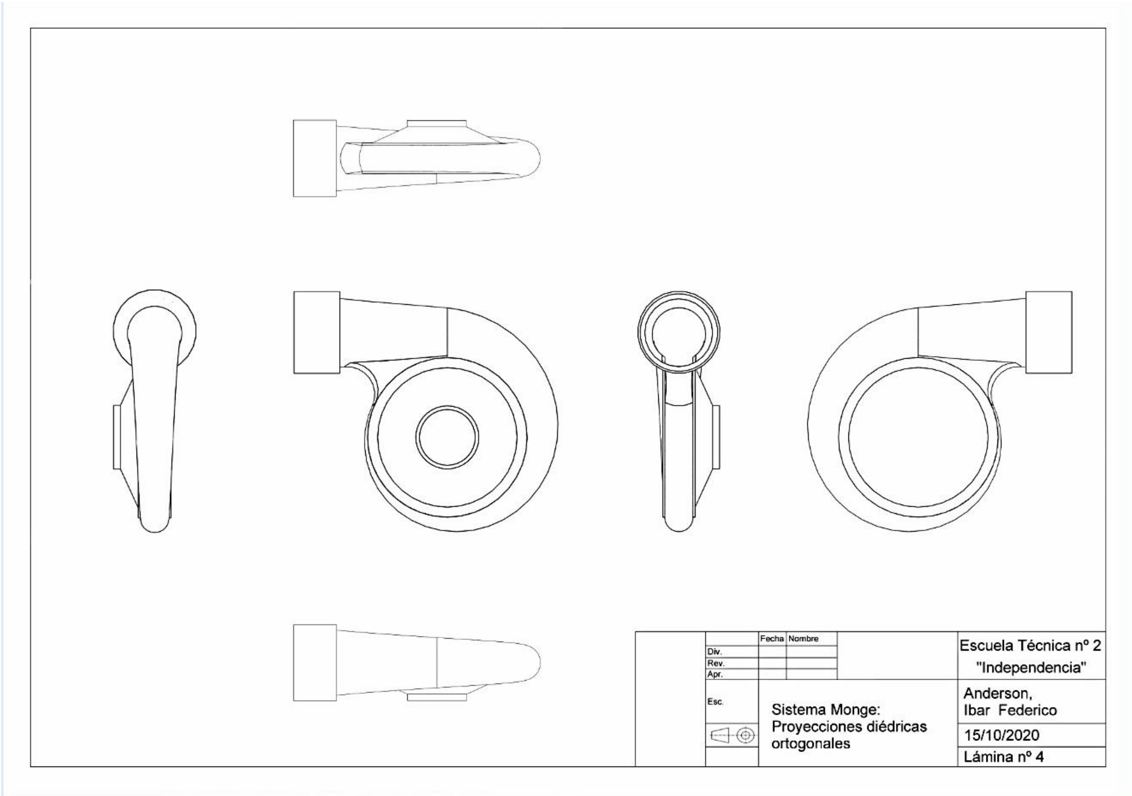


Figure 33. Monge system: orthogonal dihedral projections of the casing: stator, impeller and volute. Source: self made.

In general terms, this innovation required taking into account the classical physical principles and the fundamental laws of electricity and magnetism such as the behavior of Ohm's Law in alternating current and the Faraday-Lenz Law and other known alternating current laws [1, 2, 3 and 4] to cite some examples that represent classical concepts on the theoretical and physical foundations of motors that explain their electro-magnetic operation. Additionally, bearing in mind a bibliography on alternating current electrical machines published in Spanish [5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15] and another in English [16, 17, 18, 19 , 20, 21, 22 and 23]. Likewise, attentive to the new and extensive specific bibliography on the approach to environmental problems and the so-called "carbon footprint", for Energy Efficiency (EE), the study has focused on a specific bibliographical review on ecodesign and energy efficiency in refrigeration and ventilation systems; taking into account a couple of personal works [24, 25, 26, 27 and 28] and other general ones and by various authors [29, 30, 31, 32, 33, 34, 35, 36, 37 and 38]. Of the seven (7) levels of the so-called Ecodesign Strategic Wheel addressed by Eng. Guillermo Canale in the Ecodesign Postgraduate course of the Department of Industrial Design of the National University of La Plata, on which the central focus has been decided is on the structure level of the product and the reduction of the impact during use and the lowest consumption of active single phase energy of 220 (Volts) and 50 (Hertz) available in the distribution system of the domestic and commercial electrical network in the Argentine Republic (non-industrial three-phase). For which a high energy efficiency fan motor has been developed that saves single-phase active energy -kilowatthour (kwh)- and was originally intended for residential and commercial use.

Prototype manufacturing stage.

The activities carried out for the construction of said prototype, of a centrifugal air blower for civil and commercial (non-industrial) use, were the following.

According to NEMA (National Association of Electrical Manufacturers), the synchronous motor that was decided to be built is of the PMSM/IPM type with ceramic magnets inserted tangentially in the rotor. The magnets are ceramic ferrite with a magnetic field of 2,000 to 4,000 (Gauss) or 0.2 to 0.4 (Tesla), the cheapest on the market; interacting with a stator of 482 (Ω) impedance (Z). In the future, it is planned to replace ferrite magnets with neodymium rare earth magnets (Nd2Fe14B) between 11000 and 14000 (Gauss) or 0.2 to 0.4 (Tesla) magnetic field strength; which is a key factor to increase energy efficiency.

The activities carried out for the construction of the prototype were: (a) coupling a synchronous or self-excited PMSM/IPM type motor obtained from the rotor-stator of a 65 (watt) nominal power dishwasher electric pump; connecting it to (b) the six radial blades of the impeller obtained from a rotor of a shaded-pole asynchronous motor (frager's turn or short-circuited turn) of a hair dryer. In this preliminary experimental stage, it was only thought of obtaining an experimental (verifiable) prototype, before obtaining a scalable minimum product for industrial production for single-phase commercial use.

The control that is achieved with the design of an LC circuit consisting of a capacitive reactance and an inductive reactance are responsible for processing the binomial expression of impedance (Z=A+jB). The capacitive reactance is obtained from a 3 (μF) capacitor connected in parallel to the two phases of the 220 (V) and 50 (Hz) single-phase alternating current (AC) emf (electromotive force) source and whose function is the power factor correction (cos de phi). The inductance is obtained from a coil analogous to a 48 (Ω) magnetic ballast connected in series to one of the phases of the emf source (electromotive force), whose function is to limit the passage of current or intensity (Amps) that passes through it (due to its inductive reactance),

Finally, the conventional prototyping of a 220 (Volts) and 50 (Hz) 2-pole PMSM/IPM synchronous motor with a volute made of GFRP (Glass-Fiber Reinforced Plastic) composite material was completed. and six (6) blades of 105 (mm) in diameter, with the exact dimensions of a microwave fan.

Therefore, the invention belongs to the technical field of starting control in PMSM/IPM electric motors and provides a method for the motor-system to control the starting of the outer radial blades of the centrifugal fan/air extractor and its subsequent energy efficiency (ee).

The starting method includes: (1) a start at rated motor power of 17.7 (Watts) active power and, (2) a pass through to the EMI-LC filter activated by the SPDT switch at 6.6 (Watts) of power active in total that make up the RLC set (capacitor + inductor coil + motor stator).

Work materials.

The work materials used correspond to the following test bench.

Figure 34. Test bench connected to the SARS-CoV-2 or Covid-19 (Coronavirus) centrifugal extractor/blower motor for stale air: Turbo. With digital multimeter (AC volt meter), clamp meter (AC current meter), frequency meter (Hertz meter), laser photometer (RPM speed meter), digital oscilloscope waveform meter alternating current in voltage (Vpeak-peak, Vavg, Vrms), for calculating the harmonic distortion crest factor, analog oscilloscope for qualitative observation of the THD (alternating current harmonic distortion), wattmeter (active power meter in watts or watts), power factor (cosine of fi), power-meter (active energy consumption meter in kilowatt-hours: kWh). Source: self made.

Figure 35. View of the frequency meter turned on indicating 50 (Hertz) of alternating current (AC), together with the digital multimeter (voltmeter) turned off. Source: self made.

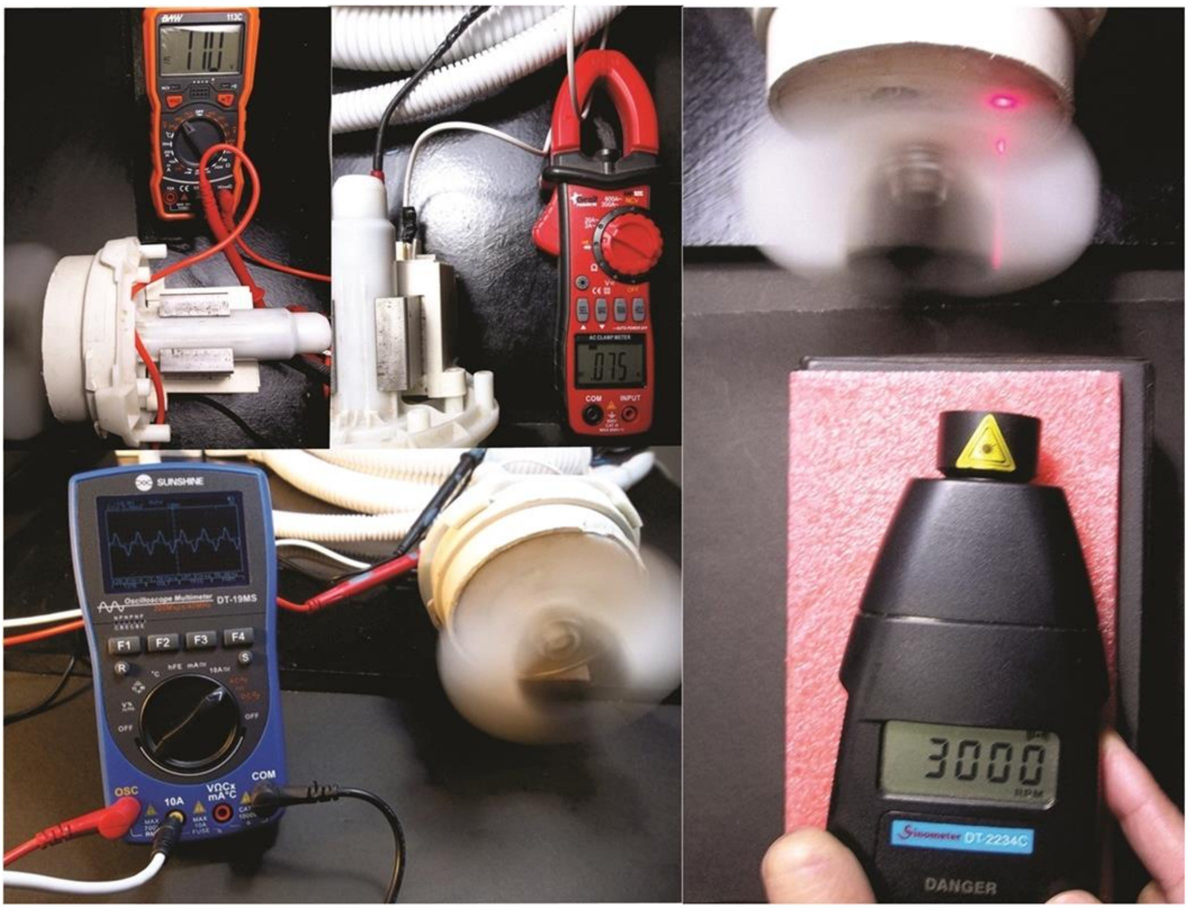


Figure 36. PMSM/IPM type synchronous motor connected to the oscilloscope showing the waveform of the non-linear voltage, also connected to the digital multimeter showing the voltage drop of 110 (volts), and to the amperometric clamp showing the drop in circulation of electric current at 0.075 (amps) and of the constant in the speed of the blade at 3000 (RPM). Source: self made.

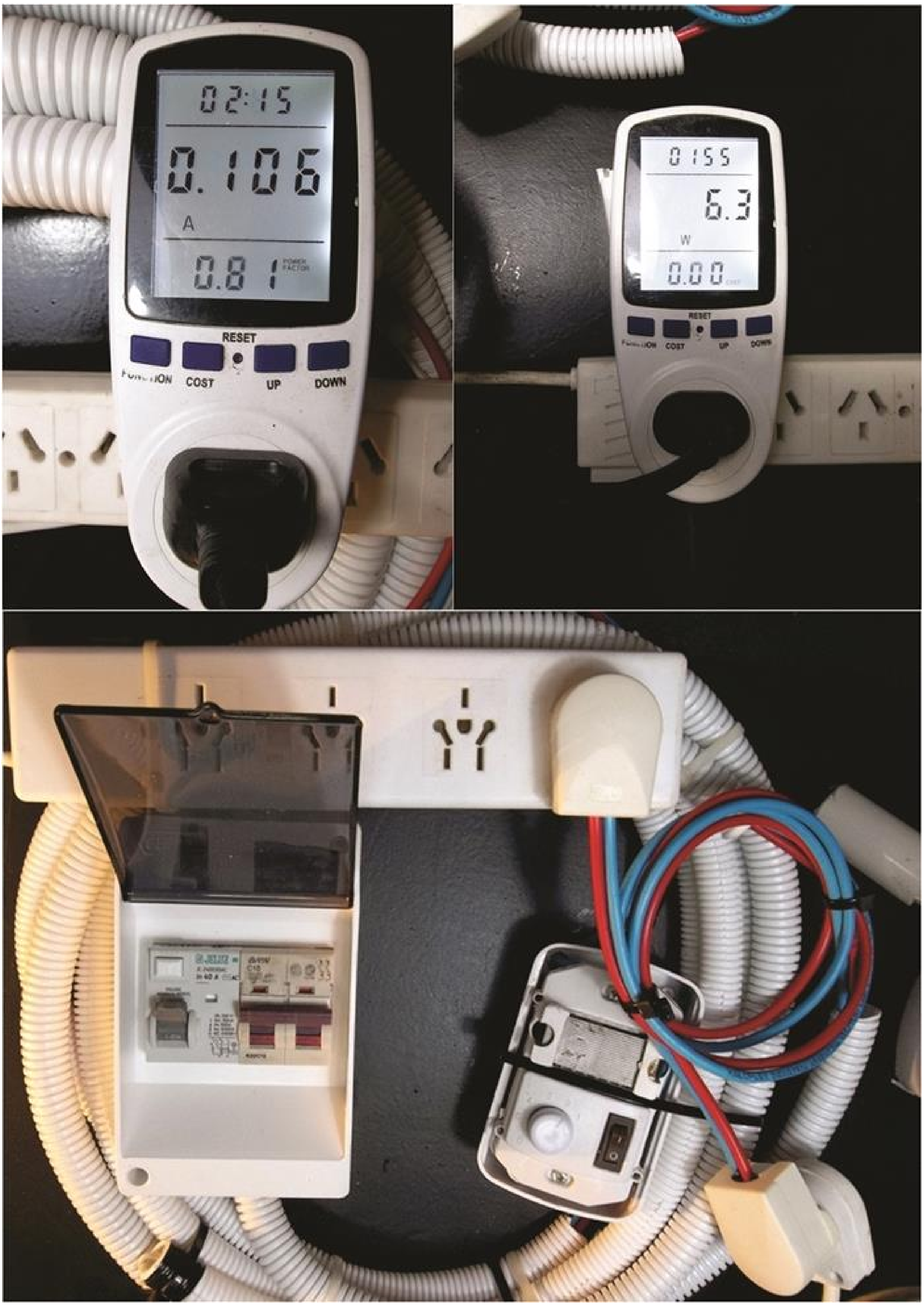
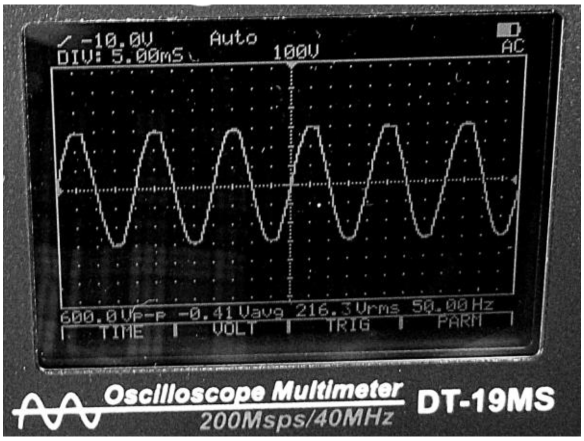
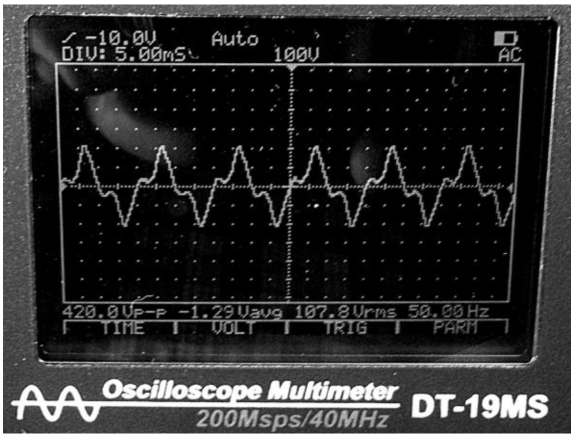


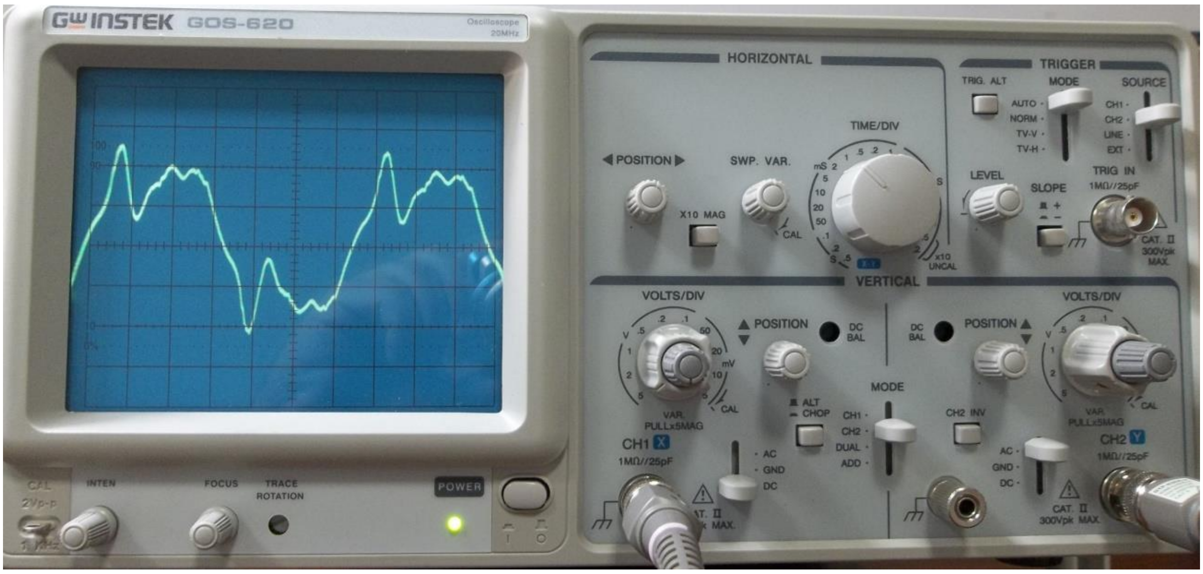
Figure 37, 38 and 39. Top left, PMSM/IPM type synchronous motor tested with energy efficiency (EE) circuit on. Active power 6.3 (watts) in all RCL circuit. Top right, power factor (pfd) equivalent to 0.81 (cos Φ). Below, detail of the electrical connections of the thermal key and the differential circuit breaker of the test bench and the inductive reactance connected in series to one phase, inside it together with the capacitor in parallel to the two (2) phases at the coupling point (downstream). The capacitor in parallel connected to the two phases, is linked to the inductive-reactance in series to one of the phases, which is the secret of the operation of the PMSM/IPM synchronous motor with low energy consumption and high Energy Efficiency (EE); its secret is kept for the claim according to the Patent Law No. 24481 modified by its similar No. 24,572 (TO 1996) and its Regulations (it is not shown to preserve the novelty and prior non-disclosure). Source: self made.

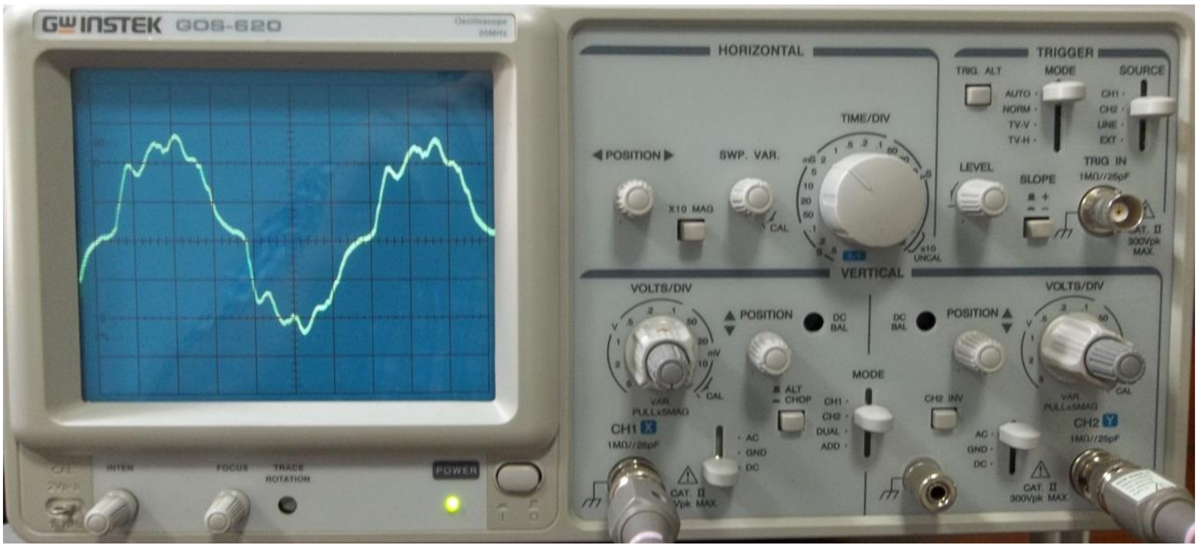




Figures 40 and 41. On the left, magnification of the image observed in the oscilloscope. The wave signal is perfectly sinusoidal when it is not connected to the Energy Efficiency (EE) system. No presence of harmonics (THD) is observed. Peak voltage 600 ($voltios_{pico}$) y 216 (V_{rms}), 50 (Hz). The basic equipment used for analysis of non-sinusoidal voltages and currents is the oscilloscope. The waveform graph on the oscilloscope provides immediate quantitative information about the degree and type of distortion; sometimes cases of resonance are identified through the visible distortions that are present in the voltage and current waveforms. No harmonic distortion is observed. Source: self made.

The crest factor (CF) is an indication of harmonics caused by the non-linear load connected to the power control of the inductive-reactor in series to one of the phases., which demands a distorted or non-sinusoidal current. For a current and voltage measurement, the crest factor value is (CF)=1.9. Source: self made.





Figures 42 and 43. To observe the harmonic distortion (THD) of the alternating current, upstream of the energy efficiency RL circuit, an AC step-down transformer was used without filtering at the output of the capacitive-inductive reactance. The oscilloscope image above shows the waveform without filtering, the image below shows the waveform filtered with a low-pass EMI (ElectroMagnetic Interference) filter (LPF) with passive elements. Source: self made.

The magnification of the image observed in the oscilloscope the wave signal is perfectly sinusoidal when it is not connected to the Energy Efficiency (EE) system. No presence of harmonics (THD) is observed. Peak voltage 600 ($voltios_{pico}$) y 216 (V_{rms}), 50 (Hz). The basic equipment used for analysis of non-sinusoidal voltages and currents is the oscilloscope. The waveform graph on the oscilloscope provides immediate quantitative information about the degree and type of distortion; sometimes cases of resonance are identified through the visible distortions that are present in the voltage and current waveforms. No harmonic distortion is observed.
The crest factor (CF) is an indication of harmonics caused by the non-linear load connected to the power control of the inductive-reactor in series to one of the phases., which demands

a distorted or non-sinusoidal current. For a current and voltage measurement, the crest factor value is (CF)=1.9.

The crest factor (CF) value data was calculated with the following formula:

$$CF = \frac{V_{peak}}{V_{rms}} = CF = \frac{420\ (Volts_{peak})}{2} = 210\ (Volts) \rightarrow \frac{210\ (Volts)}{107.8\ (Volts_{RMS})} = 1{,}948$$

After its simulation in three dimensions (3D), we proceeded to the physical construction of the product and its parts. 3D simulation is generally used as a procedure, among other things, to save money and experimental time; to correct variables such as dimensions, volumes, sizes, assemblies between parts and pieces, form and function relationships, aspects that are not only functional and aesthetic, but also ergonomic, etc. This is analyzed in the next stage of manufacturing the prototype.

The central idea of technological innovation (R+D+i) of Energy Efficiency (EE) is inspired by line no. 15 of invention patent no. 381968 of the electrical engineer Nikola Tesla, dated May 1, 1888 (inventor of the alternating current system that today is used throughout the world), in effect as cited in point No. 15 of the aforementioned patent: *"15: Such a solution, mainly, requires speed uniformity in the motor regardless of its charge within its normal working limits"* (Tesla, 1887: US381968A) [37].

But the patent of the invention, here it was innovated, not in conventional a-synchronous induction motors (as originally proposed by Tesla), but in PMSM/IPM type synchronous motors (Permanent Magnet Synchronous Motor/Interior Permanent Magnet); to increase the energy efficiency (EE) of motor performance without the need to use complex electronics such as variable frequency drives (VDF) or variable speed drives frequently used in induction motors.

A synchronous machine is an alternating current rotating electrical machine whose permanent speed of rotation is linked to the frequency of the voltage at the terminals and the number of pairs of poles. The speed variation problem has been solved by altering the "scalar control" of the Command Law; that is, keeping the voltage/frequency relationship (Volts/Hertz) non-constant. The principle was solved by electromechanical means, physically more resistant to work and with less generation of harmonics than an electronic design with Triac. Which constitutes a study prior to the development of another prototype, antecedent of this development, where the use of electronics was analyzed [24, 25, 26, 27 and 28].

How motors produce torque due to flux in their rotating field. When operating below its base speed, torque is delivered by keeping the voltage/frequency ratio (Volts/Hertz) applied to the motor constant. This is what VFDs do to regulate speed while maintaining torque. So if the motor speed is reduced, because the voltage drops, the frequency must drop for the voltage/frequency ratio to remain constant. If the Volts/Hertz ratio increases by reducing the frequency to slow the motor, the current will increase and become excessive. If, on the other hand, the Volts/Hertz ratio is reduced by increasing the frequency to increase the speed of the motor, the torque capacity will be reduced.

But in the design proposed here, the Volts/Hetz ratio is not constant and we reiterate that the decrease in torque does not affect the normal operation and/or work of the motor; on the contrary, it reduces vibrations, decibels (not measured), and consequently reduces the temperature rise of the parts and/or mechanical parts of the electrical machine due to the transformation of electromechanical energy into thermal energy. This results in an improvement in Energy Efficiency (EE).

As the motor operates with a light load (air flow), the Volts/Hertz ratio can be reduced to minimize the motor current, and because a lower voltage is applied, the magnetizing current is reduced and consequently, a lower current is produced as well. The lower torque is still tolerable by the engine.

As stated, reducing the Volts/Hertz (V/Hz) ratio with increasing frequency to increase motor speed will reduce torque capacity. Indeed, although the motor torque decreased, what is truly surprising is that for the load (propellers connected to the motor shaft) the rotational speed (RPM) of the six (6) blades connected to the rotor shaft did not decrease (verifying what he stated Nikola Tesla in line no. 15 of his patent: US381968A from 1887); therefore, the ability to perform mechanical work (Joules) on fluid air did not decrease (although he was referring to a-synchronous and non-synchronous induction motors, such as the one proposed in this development). This is technological innovation.
The motor presents a drop in the rated power of the motor of 17.7 (Watts) with the Energy Efficiency (EE) circuit "off", when "turned on" it was reduced to 6.3 (Watts), in the total circuit RCL. Without losing speed in the rotation of the rotor (6 radial blades); that is to say, without diminishing the capacity to carry out mechanical work (Joules) on the blades of the centrifugal turbine. This is known as energy efficiency (EE).
Since the motor is running with a light load (air fluid), the Volts/Hertz ratio can be reduced to minimize motor current; and because a lower voltage is applied it is also possible to reduce the magnetizing current and consequently produce a lower torque which is still optimal for normal motor operation (pushing it to the limit of its operable physical capabilities as you described in his patent Nikola Tesla). Maintaining the non-constant voltage/frequency relationship, although with a decrease in torque.
For this reason, with the aim of obtaining a voltage wave attenuator (Volts) and current intensity (Amps), which works as a limiter of the electric current as well as a low-pass EMI (ElectroMagnetic Interference) filter. (LPF); the Energy Efficiency (EE) circuit was designed with passive elements whose topology is inductive-capacitive: LC.
In the design proposed here, the inductor "L" is connected in series and the capacitor "C" is connected in parallel", forming an LC design for the low-pass filter, which reduces the ripple ripple in the input voltage. output and produces a drop in the input average voltage (Vavg).
The innovation here lies in the fact that the analysis of first-order linear filter circuits has a cut-off frequency ($\omega c=1/LC$) of the inductive-capacitive type that works by analogy to a resistive-capacitive one, that is, ($\omega c=R/ L$). Since we can assume that in the inductor the inductive reactance operates simultaneously as a resistance that reduces the flow of electric current (Amps) with the consequent voltage drop (Volts) from the output to the load and as an energy storage tank in the form of a magnetic field that is returned to the grid for consumption; while in the capacitor the capacitive-reactance stores the energy in the form of an electric field, both linear circuits filter the harmonics present in the sinusoidal wave of the alternating current.
The importance of using an inductive reactance has a double meaning: (a) as a passive component of the low pass filter (LPF), since it reduces the ripple ripple in the output voltage acting as a harmonic filter and subsequently; (b) produces a drop in the average input voltage (Vavg), that is, it produces a voltage drop from 220 (Volts) to 110 (Volts), which in the calculation of the active power formula will produce a drop in the engine power (no loss of rpm or loss of engine speed). That is, without affecting its ability to perform mechanical work (Joules).

Results and Discussion.

This stage of proof or testing will end up confirming (affirming) as "true" line no. 15 of Nikola Tesla's invention patent no. this work was initially executed). As anticipated in the introduction.
The load on the motor shaft are the centrifugal blades, whose value is expressed in ω, which is the angular velocity measured in radians/second: 314.159 (rad/s). Equivalent to 3000 revolutions per minute (RPM) obtained by the converter from (rad/s) to (RPM). Said 3000 (RPM) correspond to a frequency of 50 (Hz).

The formula for the average active power (Pmed), in a general RCL circuit of alternating current (AC) is equal to the product of the effective voltage (Vrms), by the effective intensity of the electrical current (Irms), multiplied by the factor power or cos phi: cos (Φ).
Exactly, according to some classical authors of physics, electricity and magnetism: "Pmed = ½.VIcos (Φ) = Vrms.Irms.cos (Φ)" (Sears-Zemansky, 2009:1076). Values that were taken with the corresponding instruments of true effective value or RMS (Root Means Square).
Then, considering the stability of the frequency (Hz) of the alternating current (AC), which in the Argentine Republic is 50 (Hertz), which ensures a constant rotation at 3000 RPM (revolutions per minute) of the motor shaft. If the pair of poles of the synchronous machine is equivalent to two (2) poles (north-south) in the stator. Being p=2, the number of poles used in the design of the prototype -according to authors in the field of electrical machines- has the following formula:

The rotor and the stator always have the same number of poles (...), the number of poles determines the synchronous speed of the motor: ns = 120 . f/p
Where:
ns = motor speed (r/min)
f = source frequency (Hz)
p = number of poles(Wildi, 2019: 379)

Characterized by the following formula:

$$ns = \frac{120.f}{p} = \frac{120.50}{2} = \frac{6000}{2} = 3000\ (RPM)$$

As mentioned earlier:
*F:*Frequency of the network to which the machine is connected (Hz).
*Q:*Number of poles that the machine has.
*ns:*Synchronous speed of the machine or revolutions per minute (RPM).
Calculation with which the constant data of the revolutions per minute (r/min or RPM) is obtained, according to the frequency of the current in the Argentine Republic: ns = 120.50 (Hz)/2 = 3000 (r/min) , or 3000 (RPM). The rotor, unlike asynchronous machines, rotates without slip at the speed of the rotating field.
The 3000 (revolutions/minutes) or 3000 (RPM), as indicated above, is a consequence of the frequency of alternating current (AC). As the motor is PMSM type; the poles (north-south) of the rotor magnets are aligned with the poles (south-north) of the stator (through which the single-phase alternating current flows), synchronously following the rotation speed.
We had previously argued that the centrifugal motor presented here does not decrease its rotor RPM when active power consumption is reduced; decreasing the active power (Watts), ergo: your active energy consumption (kWh) decreases. But it had been noticed that the same did not happen with the torque, since it descends to the minimum limit, without affecting the capacity of the rotor blades to carry out mechanical work (Joules) in the air.
In the International System of Units (SI), the unit of torque (also called: torque) is the physical quantity: Newtons.meters (abbreviated: Nm). Torque is the moment of a force exerted on the power transmission shaft (rotor). According to certain authors, from the rotation power formula we know that: "P=.ω" (Tipler-Mosca, 2006:265).τ
where each algebraic symbol means:
P, is the power (measured in Watts).
τ, is the engine torque (measured in Nm). Represented by the letter of the Greek alphabet: tau.
ω, is the angular velocity (measured in rad/s). Represented by the letter of the Greek alphabet: omega.

In both situations (without inductive reactance and with inductive reactance connected in series to one of the phases), the angular speed ω (represented by omega), or speed of rotation measured in radians/second (rad/s) is the same: 314.159 (rad/s). Equivalent to 3000 (RPM) obtained by the alternating current frequency of 50 (Hz).
Analyzing the power values at the motor input, only of the motor and not of the total RCL circuit, we obtain the following values with the Energy Efficiency (EE) circuit: "off" and "on".
Solving the torque-motor (tau) or torque, we obtain the following values: 0.057 (Newtons*meters) with the key "off" and 0.025 (Newtons*meters) with the key "on".
According to the "Fan Affinity Law" specified in the UNE 100-230-95 Standard, the power absorbed by a fan with an a-synchronous motor varies with the cube of its speed. This means that for a small variation in rotational speed, the power changes considerably. This has great implications from the point of view of energy efficiency (EE) since by reducing the rotational speed of the centrifugal fan blades by 23.7% (measured in revolutions per minute), the mechanical power (measured in watts) supplied to the fan is reduced by 56%.
Power (W) and speed (RPM) variables determined according to International Standards ISO 5801-96(E) and WD 13348-1998.
Considering that the "Fan Affinity Law" applies to a-synchronous motors and does not apply to synchronous motors, such as the one used in the project; the energy efficiency (EE) advantage is significantly higher (and impossible to compare since there is no International Standard establishing such benchmarks). Given that in the conventional a-synchronous motor (single-phase induction) the speed of rotation of the blades should be reduced by 23.7% for a reduction of 56% of the active power (Watts) of the motor; here the speed is not reduced because the motor is synchronous and keeps the 3000 (RPM) as a consequence of the frequency of the alternating current: 50 (Hz).
Which, on the other hand, induced the motor to operate by reducing the Volts/Hertz ratio and decreasing the torque of the motor and its capacity to provide constant output power.
As motors produce torque due to flux in their rotating field. When operating below its base speed, the torque is carried out by keeping the voltage/frequency ratio (Volts/Hertz) that is applied to the motor constant. This is what the VDF (Variable Frequency Drives) do to regulate the speed, maintaining the torque. So if the motor speed is reduced, because the voltage drops; the frequency must drop so that the voltage/frequency ratio remains constant and the core of the motor does not saturate, generating harmonic distortion (THD).

Table 5. The data of the PMSM/IPM type synchronous motor calculated by formulas and data extracted by laboratory instruments (with the energy efficiency system "off") are detailed below in the following table with their respective formulas, values and units physical. Source: self made

Denomination	**Formula**	**Worth**	**units**
active power	$P = V_{rms}.I_{rms}.\text{Cos}\,\emptyset$	17.7	(W) : Watts
effective voltage	$V_{RMS} = \frac{V_{pico}}{\sqrt{2}}$	220	(V) : Volts
effective current	$I_{RMS} = \frac{I_{pico}}{\sqrt{2}}$	0.456	(A) : Amps
Power factor (cos phi)	$\text{Cos}\,\emptyset$	0.17	(nls)
Reactive power	$Q = X_L.I_{RMS}{}^2$	98.73	(VAr) : Volt-Amp Reactive
Apparent power	$S = V.I$	100.32	(VA) : Volt-amps
Total impedance RL	$Z_{RL} = \frac{V_{RMS}}{I_{RMS}}$	482.4	(Ω) = Ohms

Endurance	$R = \frac{P}{{I_{RMS}}^2}$	85.12	(Ω)
inductive reactance	$X_L = \sqrt{Z^2 - R^2}$	474.83	(Ω)
Angular frequency (pulsations)	$\omega = 2.\pi.f$	314,159	(Rad/S) : Radians/Seconds
Grid frequency	f	fifty	(Hz) : Hertz
Inductance	$L = \frac{X_L}{2.\pi.f}$	1.51	(H) : Henrys
Phase shift between total voltage and total current$(V_T)(I_T)$	Inductive circuit, the voltage leads the current.	79.82 (º) 1.39 (Rads)	(º) : Degrees (Rad) : Radians
Impeller blade speed	$ns = \frac{120.f}{p}$	3000	(RPM) : Revolutions per minute

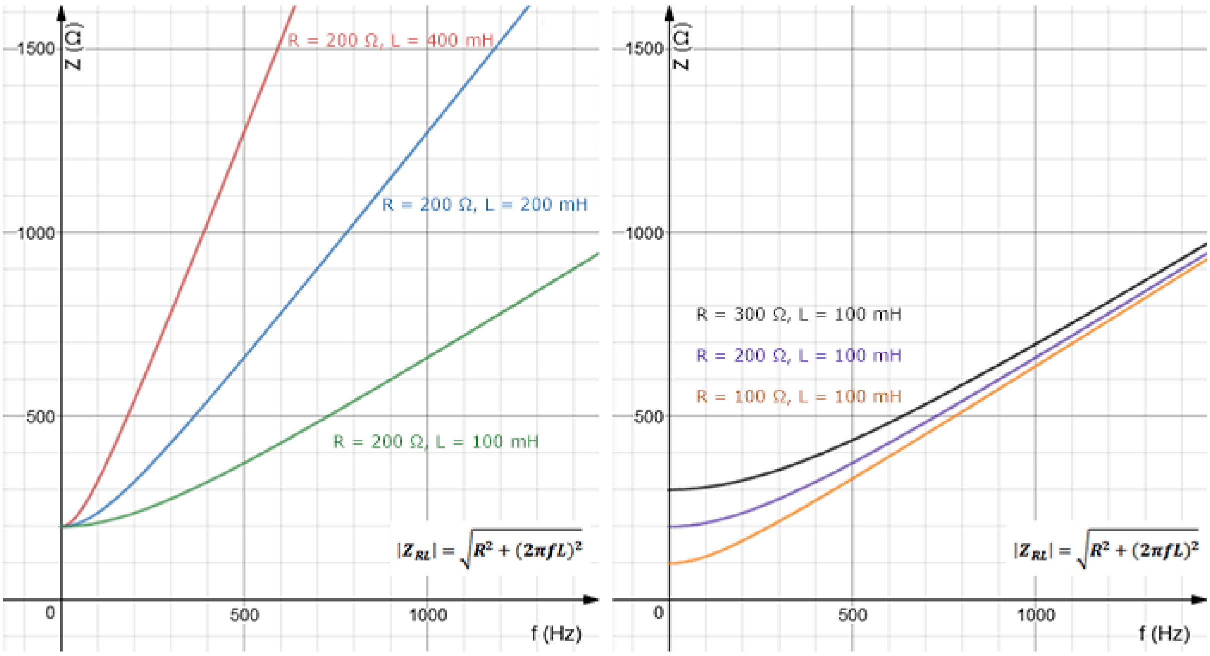


Figure 44. A plot of the ZRL impedance of the series RL circuit against the frequency f for a given inductance and resistance. Source: self made.

PMSM type motors provide a shaft rotation at a fixed speed in synchrony with the power supply frequency regardless of the fluctuation of the mechanical load –greater or less- that produces resistant torque. The voltage (Volts) and intensity (Amps) of the current decrease when the inductive reactance (Z1) acts together with the capacitor (C1); and anyway, the motor runs at synchronous speed, as long as the mains frequency is constant, in this case 50 (Hz) for any torque up to the motor's operating limit.

This joint effect is achieved by the combined work of the impedance (Z1) in series with one phase plus the capacitor (C1) in parallel with the two phases.

A perfect inductor would not generate Joule losses, limiting the current through the inductor without generating lower performance. In reality, an inductor has some internal resistance, and consequently Joule losses are minimized but not eliminated. But used in the design of the energy efficiency (EE) system for the motor, its reactance limits the current available

with minimal power losses in the inductor. The ballast is also commonly known as a reactance, since due to the alternating current the coil presents an inductive reactance.
Impedance (Z) is a measure of opposition that a circuit presents to a current when a voltage is applied. Impedance extends the concept of resistance to alternating current (AC) circuits, and has both magnitude and phase, unlike resistance, which only has magnitude. When a circuit is supplied with direct current (DC), its impedance is equal to the resistance, which can be interpreted as the zero phase angle impedance.
By definition, impedance (Z) is the relationship (quotient) between the voltage phasor and the current intensity phasor.
In electronics and electrotechnics, the opposition offered to the passage of alternating current by inductors (coils) and condensers (capacitors) is called reactance, it is measured in ohms and its symbol is (Ω). Together with the electrical resistance, they determine the total impedance of a component or circuit, in such a way that the reactance (X) is the imaginary part of the impedance (Z) and the resistance (R) is the real part, according to the following equality:
$Z = R + jX$, binomial representation.
When alternating current flows through one of the two elements that have a reactance, the energy is alternately stored and released in the form of a magnetic field, in the case of coils, or an electric field, in the case of capacitors.
However, actual coils and capacitors have an associated resistance, which in the case of coils is considered to be in series with the element, and in the case of capacitors in parallel. In those cases, as already indicated above, the impedance is (Z).
When the inductive reactance (Z1) its value is Z=48 (Ω) is activated with the key (S3), said reactance is in charge of processing the binomial expression of the impedance (Z=A+jB); where (A=Resistance) is the real part, (j) is the imaginary unit and where (B=X) is the reactance in ohms, it causes the voltage at the input to the motor to drop from 220 (V) to 97 (V) and the current drops from 0.6 (A) to 0.105 (A). But the synchronous speed of the motor shaft connected to the six (6) radial blades of the impeller does not lose speed. Which demonstrates energy efficiency (EE).
The incorporation of the inductive reactance (Z1) in one of the phases, which has improved the power factor or cosine of fi, from 0.22 to 0.41 and without the capacitor (C1) (which meant a considerable increase or improvement of energy efficiency). With the capacitor connected this value rises from 0.17 to 0.81.
The testing was carried out on a test bench, designed for this purpose, with two (2) oscilloscopes -one analog and the other portable digital- to observe and measure the waveform quantitatively and qualitatively (signal harmonic distortion: THD), peak-to-peak voltage (Voltsp-p) waveform signal meter, true RMS or (in English: True RMS) of the average voltage (in English: average, AVG) or average voltage (Vavg). With a digital multimeter that measures voltage (Vrms), a frequency meter that measures alternating current oscillation (Hz), an amperometric clamp meter that measures amperes (A), a cosine phi meter (cos Φ), a wattmeter that measures power active in watts (W),

Table 6. Values of the PMSM/IPM type synchronous motor calculated by formula and other data obtained by laboratory instruments are detailed in the following table (with the energy efficiency system "on") with their respective formulas, values and physical units . Source: self made.

Denomination	Formula	Worth	units
active power	$P = V_{rms}.I_{rms}.\mathrm{Cos}\ \emptyset$	6.3	(W) : Watts
effective voltage	$V_{RMS} = \frac{V_{pico}}{\sqrt{2}}$	110	(V) : Volts

effective current	$I_{RMS} = \frac{I_{pico}}{\sqrt{2}}$	0.106	(C) : Amps
Power factor (cos phi)	$\text{Cos } \emptyset$	0.8	(nls)
Reactive power	$Q = \text{Sen } \emptyset. \ \frac{P}{\text{Cos } \emptyset}$	4,725	(VAr) : Volt-Amp Reactive
Apparent power	$S = \sqrt{P^2 + Q^2}$	7,875	(VA) : Volt-amps
Total impedance RL	$Z_{RL} = \frac{V_{RMS}}{I_{RMS}}$	482.4	(Ω) = Ohms
Endurance	$R = \frac{P}{{I_{RMS}}^2}$	85.12	(Ω)
inductive reactance	$X_L = \sqrt{Z^2 - R^2}$	474.83	(Ω)
capacitive reactance	$X_c = \frac{1}{2.\pi.f.C}$	1,061	(kΩ) : Kilohm
total LC impedance	$Z_{LC} = 2.\pi.f.L - \frac{1}{2.\pi.f.C}$	857.97	(Ω)
Angular frequency (pulsations)	$\omega = 2.\pi.f$	314,159	(Rad/S) : Radians/Seconds
Grid frequency	f	fifty	(Hz) : Hertz
Inductance	$L = \frac{X_L}{2.\pi.f}$	1.51	(H) : Henrys
capacitance	$C = \frac{1}{\omega.X_c}$	3	(: MicrofaradsμF)
Phase shift between total voltage and total current$(V_T)(I_T)$	Inductive circuit, the voltage leads the current.	90 (º) 1.5708 (Rads)	(º) : Degrees (Rad) : Radians
Impeller blade speed	$ns = \frac{120.f}{p}$	3000	(RPM) : Revolutions per minute
resonant frequency	$f = \frac{1}{2\pi\sqrt{L.C}}$	74.77	(Hz) :Hertz

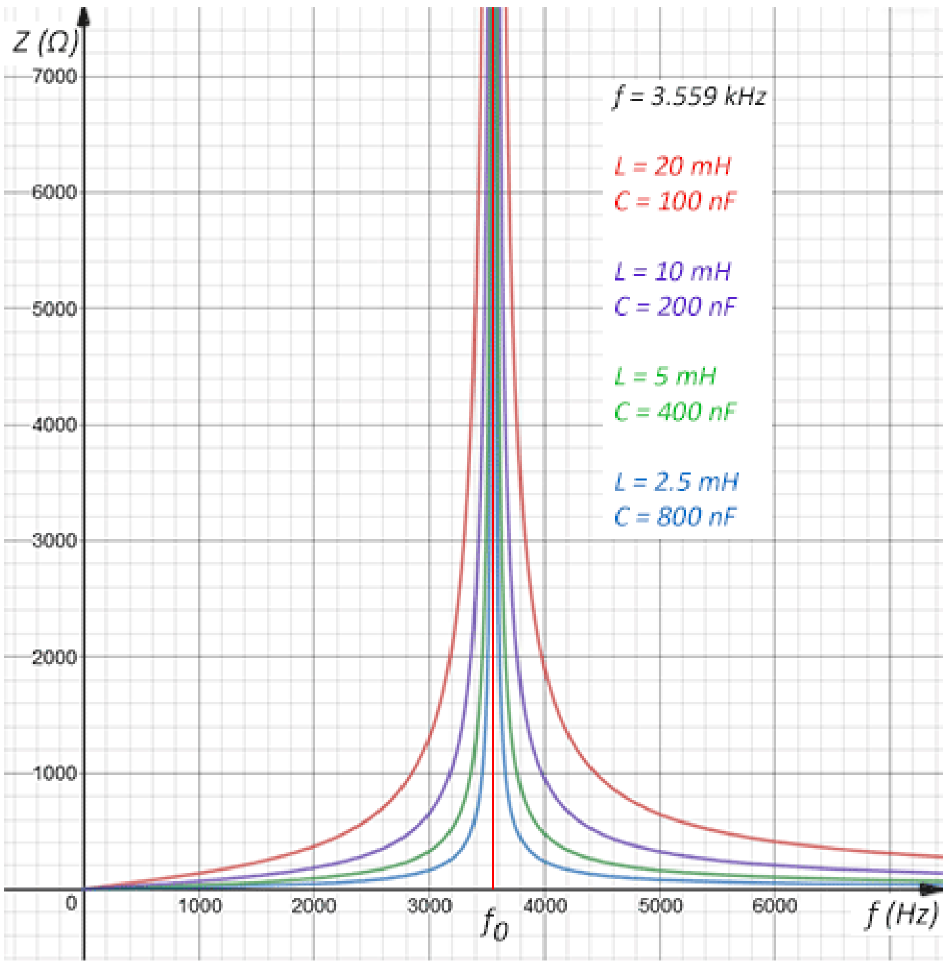


Figure 45. Plot of ZLC impedance versus frequency f of several ideal parallel LC circuits for a given inductance and capacitance; the resonant frequency of 3.559 kHz is the same for all LC circuits. Source: self made.

Conclusions

The non-soft start of the motor, at the beginning of its ignition, is due to the need for the nominal active power of the static starting torque required by the mass of the load (radial blades connected to the rotor shaft) that must be accelerated. Non-soft start does not save energy due to the initial power demand of the motor at start-up time; but this only lasts for an instant (2-3 seconds), once the synchronous speed of 3000 (RPM) is reached, it is manually switched to Energy Efficiency (EE) mode. Mode change to Energy Efficiency (EE) is achieved via mechanical contacts or SPDT switch.

Regardless of whether the SPDT switch is in “off” or “on” mode in energy efficiency (EE) mode, in both cases the AC frequency always acts at 50 (Hertz). For this reason, the motor, although its torque decreases, does not decrease its speed or its ability to perform mechanical work on the radial blades (as long as the motor torque does not decrease the torque below the minimum limit required to keep the rotor running at sync speed).

Indeed, the electromechanical design hypothesis is clearly oriented in the right direction, since the harmonics decrease (the sinusoidal signal of the alternating current is rectified, as observed in the shape of the voltage wave observed in the oscilloscope), although the signal indicates that the load is still non-linear and requires a low-pass EMI (electromagnetic interference) filter (LPF) with passive elements in its construction.

Additionally, other information that resulted from the analysis of the data is that there is no harmonic alteration of the frequency of 50 (Hz), since the electromechanical design of the passive low-pass filter "LC" acts in a double sense as:

-(a) a voltage reducer producing a voltage drop from 220 (Volts) to 110 (Volts) and current from 0.45 (Amps) to 0.1 (Amperes) raising the power factor to 0, 17 (Cos Φ) to 0.81 (Cos Φ) which in the calculation of the active power formula in alternating current (AC) circuits will produce a drop in motor power without loss of rotor speed (RPM); that is, without affecting its ability to perform mechanical work (Joules). Meanwhile, active power (Watts) and energy consumption measured in kilowatt-hours (kWh) decrease by 56%, with no drop in revolutions per minute (RPM) of the centrifugal blades connected to the synchronous rotor shaft.

-(b) as a ripple reducer of the output voltage or low-pass filter (LPF) of electromechanical interference (EMI) allowing the total harmonic distortion values to be maintained at: THDv<5% (normal situation) and THDi<10% (normal situation), according to the IEEE 519 standard. Reducing the ripple in the output voltage acting as a harmonic filter.

Reiterating that, while the active power (watts) decreases and the consumption of active energy measured in kilowatt-hours (kWh) also decreases, the same does not happen with its working speed (as is the case with any conventional centrifugal fan/extractor). connected to an asynchronous motor).

From the experimental conclusions, evidently the PMSM/IPM type synchronous motor does not lose speed, since it works at 100% of its maximum speed of 3000 (RPM), with only 35.6% of its maximum active power, using only 6 .3 (Watts) of the 17 nominal with which it operates at start-up. Although it is built to work up to an operating limit of 50 (Watts).

By way of comparison, a single-phase induction motor, of those normally used in refrigeration or ventilation equipment, is a “frager” type brushless a-synchronous motor (in short circuit) and works with a maximum speed of 1690 (RPM) with 100% of its maximum active power of 19 (Watts); which means 44% less speed when compared to the highly energy efficient motor developed here. In contrast, the PMSM/IPM type synchronous motor designed for this project (with the energy efficiency system “on”) works at 100% of its maximum speed of 3000 (RPM) with only 35.6% of its active power. maximum, using only 6.3 (Watts);

So we can ensure that the synchronous motor saves 67% of active energy (kWh), doing 56% more mechanical work on air fluid with the same active power (Watts).

It should be clarified that in other countries where the frequency of alternating current (AC) is 60 (Hertz) the efficiency of this electro-mechanical design would be higher, taking the motor speed from 3000 (RPM) to 3600 (RPM); much more than the 1690 (RPM) of the same a-synchronous motor at 60 (Hz) but with a 64.4% higher consumption of active energy. That is to say that if in the country where the single-phase alternating current is 60 (Hz), the a-synchronous motor of 19 (Watts) of active power, would have a speed of 1690 (RPM); but in the same country of 60 (Hz) the PMSM/IPM type synchronous motor with 6.3 (Watts) would have a speed of 3600 (RPM) with the same six (6) radial blades (the same weight and diameter of the impeller or impeller vanes of the air fluid).

Another advantage of the PMSM/IPM type synchronous motor is the following, if we apply the so-called "Fan Affinity Law", specified in the UNE 100-230-95 Standard, the way in which the power variables are affected (Watts) and speed (RPM) (determined according to international standards ISO 5801-96(E) and ED 13348-1998) is as follows: the a-synchronous motor, with a power of 19 (Watts) at 1690 (RPM) speed of the impeller blades would require 106 (Watts) of active power to equal the 3000 (RPM) of the PMSM/IPM type synchronous motor. This means that normally any refrigeration single-phase induction a-synchronous motor would require 16.8 times more active power to match this highly energy efficient design.

Therefore, this experimentally proposed design reduces active power (Watts) and active energy consumption (kWh) by 67%. Performing 56% more mechanical work (Joules) on fluid air (with a 50% reduction in carbon footprint).

That is why we say that the experimental prototype presented here is more energetically efficient (EE), because it performs more mechanical work (Joules) on the impeller blades in the air fluid, with less power (Watts), consuming less electrical energy measured in kilowatt-hours. (kWh) than the brushless a-synchronous motor (of the frager or conventional induction type used in centrifugal fans/extractors) but at higher revolutions per minute (RPM) than conventional a-synchronous motors used in air conditioning equipment. ventilation, extractors and blowers. The advantage is double.

Therefore, based on the experimental results, it can be seen that centrifugal fans can be developed that save electrical energy (kWh) without the need to resort to: (a) the use of variable speed drives (VDF) or frequency, or (b) the "Fan Affinity Law". The latter would change everything that is known in the world about the "Fan affinity law" and would imply a new bibliographic review and experimental development (new comparative studies such as the one developed here); since it is estimated that new and substantial comparative advantages could be created and developed that lead to energy saving and efficiency (never studied before, creating new fields and lines of research). Which would bring enormous global savings in the cost of electrical energy with simpler technology, although rudimentary and limited; but effective, economical, rustic (electromechanical and not electronic) and resistant to extreme working conditions.

The added value proposition comes hand in hand with Energy Efficiency (EE), which determines the reduction of the "carbon footprint"; where we went from consuming 202 (kWh) per year equivalent to 0.1 tons of CO_2 to 97 (kWh) per year equivalent to 0.05 tons of CO_2 (which means a 50% reduction in the carbon footprint) that our development of the prototype leaves on Planet Earth (to the small scale of the prototype experienced). Therefore, the relationship with the carbon footprint is directly proportional to the power of the motor and to future prototypes with greater power (the relationship in industrial three-phase motors has not been studied).

Obtaining this experimental minimum viable product is estimated to be scalable to higher single-phase power either for commercial use and to a three-phase model (star-delta connection) for industrial use (although the latter has not been tested).

Therefore, we could well describe this technological innovation as a hertzian engine.

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Figure 46. The day I was awarded for the project in the 16th INNOVAR National Contest of the Ministry of Science and Technology of the Nation. Argentinian republic. Fountain:

Figure 47. The day I was awarded for the project in the 16th INNOVAR National Contest of the Ministry of Science and Technology of the Nation. Argentinian republic. Fountain:https://www.innovar.mincyt.gob.ar/

Figure 48. Proof of the Winning Project Award (top right of the certificate). Fountain:https://www.innovar.mincyt.gob.ar/

Figure 49. Trophies of the Awards delivered in the year 2021. Source:https://www.innovar.mincyt.gob.ar/

Figure 50. Trophy received for the award of the winning project. Fountain:https://www.innovar.mincyt.gob.ar/

Bibliographic references.

[1] Resnick, R.; Halliday, D.; Krane, K; (2007). Physics, Vol. 2 (6th Edition). Mexico: Patria Publishing Group. [Online]. Recovered from:https://www.academia.edu/31428733/F%C3%ADsica_Vol_2_Halliday_Resnick_and_Krane_5th_Edition_Espa%C3%B1ol

[2] Sears; Zemansky. (2009). University Physics with Modern Physics, Volume 2, Mexico: Pearson Education. [Online]. Recovered from:https://www.u-cursos.cl/usuario/42103e5ee2ce7442a3921d69b0200c93/mi_blog/r/Fisica_General_-_Fisica_Universitaria_Vol_2__ed_12%28Sears-Zemansky%29.pdf

[3] Serway, R.; Jewett, JW (2008). Physics for science and engineering with modern physics, V. II. (7th Edition). Spain: Cengage Learning Publishers. [Online]. Recovered from:https://www.academia.edu/27915502/Serway_7_Edicion_2_Volumen

[4] Tipler, PA; Mosca, G. Physics for science and technology (5th Edition). Barcelona: Editorial REVERTÉ, 2006 [Online]. Recovered from:file:///C:/Users/Usuario/Downloads/Fisica_Tipler_mosca_vol._1_5o_edicion._e.pdf

[5] Aller, JM (2008). Rotating electrical machines. Caracas: Simón Bolívar University Editorial. [Online]. Recovered from:http://prof.usb.ve/jaller/Maquinas1.pdf

[6] Chapman, SJ (1987). Electrical machines (5th Edition). Mexico: Mc Graw Hill. [Online]. Recovered from:https://frrq.cvg.utn.edu.ar/pluginfile.php/20762/mod_resource/content/1/Maquinas-electricas-Chapman-5ta-edicion-pdf.pdf

[7] Contreras Villamizar, EF; Sánchez Rodríguez, R. (2010). Design and construction of a practical bench in electric motors, as support for the subject design of machines II. Colombia: Industrial University of Santander. [Online]. Recovered from:https://docplayer.es/7240795-Diseno-y-construccion-de-un-banco-de-practicas-en-motores-electricos-como-apoyo-a-la-asignatura-diseno-de-maquinas-ii. html

[8] Fitzgerald, AE; Kingsley, Ch.; Umans, SD (s/f). Electrical machines (6th Edition). Mexico: Mc Graw Hill. [Online]. Recovered from:https://www.academia.edu/17314182/maquinas_electricas

[9] Fitzgerald, AE; Kingsley, Ch.; Kusko, A. (1975). Theory and analysis of electrical machines. Barcelona: Hispano-European Editorial. [Online]. Recovered from:https://es.scribd.com/document/185915953/theory-and-analysis-of-electrical-machines-fitzgerald-kingsley-kusko

[10] Fraile Mora, J. (2008). Electrical machines (6th Edition). Madrid: Mc Graw Hill. [Online]. Recovered from:https://www.academia.edu/42010234/Maquinas_electricas_6a_ed_Fraile_Mora_Jesus

[11] Harper, G. (2006). The ABC of electrical machines II. Alternating current motors. Mexico: Noriega Publishing Group. [Online]. Recovered from: https://www.academia.edu/15986437/EL_ABC_DE_LAS_MAQUINAS_ELECTRICAS_VOL_2_MOTORES_DE_CORRIENTE_ALTERNA

[12] Harper, G. (2006). The ABC of electrical machines III. Installation and control of alternating current motors. Mexico: Noriega Publishing Group. [Online]. Recovered from:https://es.scribd.com/document/388385650/El-ABC-de-La-Maquinas-Electricas-Instalacion-y-Control-de-Motores-de-Corriente-Alterna-Enrique-Harper-pdf

[13] Mohan, N.; Undeland, TM; Robbins, W. (2009). POWER ELECTRONICS. Converters, applications and design (3rd Edition). Mexico: Mc Grag Hill. [Online]. Recovered from:https://lc.fie.umich.mx/~jorgeahb/Pagina/materias/PIES/electronica-de-potencia-mohan-3ra-edicion.pdf

[15] Vargas-Machuca Saldariaga, F. (1990). Rotating electrical machines. Peru: Megaprint Editions. [Online]. Recovered

from:https://repositorio.pucp.edu.pe/index/bitstream/handle/123456789/28690/maquinas_electricas_rotativas.pdf?sequence=1&isAllowed=y

[16] "CanMOST - The Canadian Motor Selection Tool," Natural Resources Canada.http://oee.nrcan.gc.ca/industrial/equipment/software/intro.cfm?attr=24

[17] "NEMA Premium Motors," National Electrical Manufacturers Association.https://www.nema.org/directory/products/nema-premium-motors

[18] "Best Practices on Motors, Pumps and Fans" US Department of Energy.http://www1.eere.energy.gov/industry/bestpractices/motors.html

[19] "The Effect of Repair / Rewinding on Motor Efficiency EASA/AEMT Rewind Study and Good Practice Guide to Maintain Motor Efficiency," EASA 2003.www.easa.com

[20] "Appliance & Equipment Standards," US Department of Energy.http://www.eere.energy.gov/buildings/appliance_stan dards/notices_rules.html

[21] Institute of Electrical and Electronics Engineers, "IEEE - The world's largest technical professional organization dedicated to advancing technology for the benefit of humanity", 2016. [Online]. Recovered from:https://www.ieee.org/index.html

[22] Thompson, SP (1895). Polyphase electric currents and alternate current motors. London: E. & FN Spon. [Online]. Recovered from:https://archive.org/details/polyphaseelectri00thomuoft/page/88/mode/2up

[23] Wildi, T. (2007). Electrical machines and power systems (6th Edition). Mexico: Pearson Education. [Online]. Recovered from:https://lc.fie.umich.mx/~jorgeahb/Pagina/materias/Libro2.pdf

[24] Anderson, IF. "Mejoras de eficiencia energética (EE) en los motores monofásicos sincrónicos de 220 (VAC)/50 (Hz), tipo PMSM". En *Rev. UIS Ing.*, vol. 18, Issue 4, pp. 57-70, 2019. Doi: https://doi.org/10.18273/revuin.v18n4-2019005 [En línea]. Recuperado de: https://revistas.uis.edu.co/index.php/revistauisingenierias/article/view/9300/9869

[25] Anderson, IF. (2019). "Eco-turbina. Turbo ventilador eléctrico 220 (VAC)–50 (Hz), de bajo consumo: eficiente energéticamente". En *Innovación y Desarrollo Tecnológico y Social*, vol. 1, Issue 1, pp. 1-28, 2019. Doi: https://doi.org/10.24215/26838559e001 [En línea]. Recuperado de: https://revistas.unlp.edu.ar/IDTS/article/view/6270/7812

[26] Anderson, IF. (2022). *Energy Efficient Centrifugal Air Extractor for Environments Contaminated With Sars-Cov-2 (Coronavirus).* [Online]. Recovered https://doi.org/10.31219/osf.io/nw6b2

[27] Anderson, IF. (2022). *Energy Efficient Centrifugal Air Extractor for Environments Contaminated With Sars-Cov-2 (Coronavirus). How to Build a Motor That Saves Electricity.* DOI: https://doi.org/10.20944/preprints202211.0307.v1

[28] Anderson, I. F. (2022). *Energy Efficient Centrifugal Air Extractor for Environments Contaminated With Sars-Cov-2 (Coronavirus). How to Build a Motor That Saves Electricity*. Preprints, 1-31. DOI: https://doi.org/10.31219/osf.io/gepbc. [Online]. Recovered http://sedici.unlp.edu.ar/handle/10915/145958

[29] Canale, G. (2013). Product Life Cycle. Contributions for use in Industrial Design. Buenos Aires: INTI. [Online]. Recovered from:https://proyectaryproducir.com.ar/wp-content/uploads/2015/09/ACV%20Libro%20A4%20Rev%20b%2016-12-13.pdf

[30] Canale, G. (2013). "Contributions of simplified ACV to the design for sustainability. Cases of industrial application". In V International Conference on Life Cycle Analysis - CILCA 2013 Mendoza: National Technological University. [Online]. Recovered from:https://proyectaryproducir.com.ar/public_html/Seminarios_Posgrado/Bibliog_obligat/CILCA%202013%20en%20castellano%20FINAL%2001-2013.pdf

[31] Canale, G. (2014). material library Environmental profile of materials (only the Introduction). [Online]. Recovered from:https://proyectaryproducir.com.ar/public_html/Seminarios_Posgrado/Bibliog_obligat/Extracto%20de%20Introducción%C3%B3n%20-%20Materialoteca.pdf

[32] Canale, G. (2010). "SOS Sustainable design. Sustainability, Economy and Design". In the 5th Ethics and Sustainability Forum. Sustainable design. Buenos Aires: 2009. Published in INTI Bulletin No. 158. [Online]. Recovered from:https://proyectaryproducir.com.ar/public_html/Seminarios_Posgrado/Bibliog_obligat/INTI%20bol158-1%20SOS%20Dise%C3%B1o%20Sustentable.pdf
[33] Technological Institute of the Canary Islands (2008). Renewable energy and energetic efficiency. Canary Islands. ITC, SA [Online]. Recovered from:https://www.cienciacanaria.es/files/Libro-de-energias-renovables-y-eficiencia-energetica.pdf
[34] Soler & Palau (2009). Practical manual of ventilation. Mexico. Editorial S&P. [Online]. Recovered from: https://www.solerpalau.mx/ASW/recursos/mven/spventilacionc2.pdf
[35] Undersecretary of Energy Saving and Efficiency (2017). Energy efficiency guide for electric motors. Buenos Aires. Ministry of Energy and Mining, Presidency of the Nation. [Online]. Recovered from: https://www.argentina.gob.ar/sites/default/files/guia_de_eficiencia_energetica_para_motores_electricos.pdf
[36] Zitron (2007). Lectures on ventilation in mines. Lime. Zitron. [Online]. Recovered from:https://fdocuments.ec/document/libro-de-ventilacion.html
[37] Tesla, N. "Electro-magnetic motor", US 381968A, 12-Oct-1887. [Online]. Recovered from:https://patents.google.com/patent/US381968A/en?oq=tesla+381968
[38] Consult the following link:https://www.ni.com

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