International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 05 - Issue 10 || October 2020 || PP. 40-43

Electric Generator Design for Low Power Wind Turbine

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Abstract: The present work consists on the design of an electric generator for a wind turbine whose nominal power reaches 2 kilowatts in normal operation conditions, which can be used for predominant wind environments in the area of Morelia Michoacán. Said design consists in the calculation of the characteristics of the winding, taking into consideration the dimensions already proposed for the wind turbine's casing, which lead to establish the cable's caliber and number of turns to reach the desired power generation, as well as the specific drawing and assembly of the related parts. This work is part of a project where we intend to manufacture a wind turbine of our own design, with similar characteristics to those currently on the market but whose manufacturing cost is much lower compared to the latter, and at the same time, we intend to seek the necessary funding for the construction and implementation of the first prototype.

Keywords: Design of an Electric Generator, Wind Turbine, characteristics of the wind, power generation.

I. INTRODUCTION

Today there is a great need to switch to new alternative energy sources that do not generate high impact on the environment. There are several types of means of obtaining this, among them, wind energy, which is an efficient, clean and generates a low impact on the environment. Although there are some drawbacks such as its construction cost, noise during operation and visual impact, it is virtues as a means of obtaining energy that does not generate waste and damage to the environment in any instance during its lifetime, make it a good means of obtaining energy through a clean and renewable source [1].Due to the environmental wear and tear produced by other energy sources, it was decided to carry out this research, as the probability of renewable energies continuing their ascent process is increasing, so the wind energy sector has all the ballots to have its future assured.

II. BACKGROUND

Due to the increasing world-wide demand of power, it is necessary to look for alternatives of generation of the same ones. Mexico has to take advantage of it isenergy potential coming from the wind, sun, water and heat of the earth. This potential opens a great opportunity to contribute to our energy security, while we join the global effort to combat climate change. Wind energy is an environmentally responsible option that allows us to maintain modern energy and comfort parameters, since it is an economically viable option. Currently, Mexico has a wind potential of more than 50,000 MW of wind energy and only about 17,000 MW are required to reach the goal of generating 35% of electric energy with clean technologies by the year 2024 [2]. The use of a wind turbine that partially covers the energy requirement emerges as an interesting project, to reduce the consumption of conventional electricity and contribute to the reduction of greenhouse effect emissions and that is easy to maintain for people with scarce economic resources. This will bring economic, social and environmental benefits.

III. OBJETIVES

To design an electric generator for a 2 kilowatt nominal wind turbine, calculating the characteristics of the generator winding to establish cable gauge and number of turns and to make the specific drawing and assembly of the parts related to the entire generation system.

IV. METHOD

In order to guarantee the correct operation of the device, it was necessary to adapt an already designed electric generator [3]; and to couple it to the dimensions and conditions to which it will have to work. In addition to some initial considerations such as a permanent magnet rotor of neodymium grade N 38 (56 pieces) and the stator with AWG 14cablewinding.

The data for the design of the wind turbine to obtain the number of turns per coil is as follows:

Air temperature $[°C]$	**Press** $\left[\frac{Kg}{m^3}\right]$	**Speed** $\left[\frac{m^2}{s}\right]$
27	1.225	1.51E-5

Design variables and algorithm parameters:

Power required $[W]$	**Radio** $[m]$	**Working speed** $\left[\frac{m}{s}\right]$	**Angular speed** $\left[\frac{rad}{s}\right]$
2000	2.6671	6.94	20.8166

$$n = \frac{60}{2\pi}\omega = 198.76\,rpm \approx 200\,rpm$$

To determine the reason for the tip speed:
Where:
ω = Angular velocity (rad/s)
r = Wind turbine radius (m).
v = Wind speed (m/s).

$$RTS = \frac{\omega \cdot r}{v} = \frac{(20.81116)(2.667)}{10} = 5.55$$

Replacing in the previously exposed values of RTS and r, one arrives at:

$$\omega = \frac{20.8166\text{v}}{2\pi 2.667}$$

Using rpm:

$$n = \frac{60}{2\pi}\omega = \frac{(20.8166)(60)\,v}{(2.667)(2\pi)} = 74.53\,v$$

Rotation speed that provides a generation frequency according to:

$$f = \frac{pv\,(74.53)}{2\pi 120} = 0.621\,pv$$

Considering a frequency of 60 Hz, speed wind of 10 m/s and a maximum wind speed, the number of poles is determined:

$$p = \frac{60}{(0.621)(10)} \approx 10\,poles$$

For all these cases more poles are required, which can be done due to the space, to have an optimal operation of the wind turbine. However, the form of operation chosen, which consists of a first stage of rectification and then another of inversion,that allows the generation to be at a frequency of 60 Hz.On the other hand, if it is desired to use the generator space to the maximum, by choosing the number of poles as a multiplepair of 3, it is possible to take advantage of the flow generated by all the magnets at all times, maximizing the use of space.Thus, 18 poles are chosen, foreseeing a scheme of 6 coils per phase, and 18 coils in total.

In this way you have:

$$f = 0.621 \cdot 18 \cdot 10 = 111.78\,Hz$$

Because of the amount of magnets and their arrangement we decided to suggest that 60 Hz is the most suitable value to work the generator. For this case, that of a three-phase generator, we have the relationship between the number of coils possible to implement and the number of poles of the generator:

$$\text{Nc} = \frac{3\text{ p}}{k} \quad ; \text{Where k} = 1,2,3 \ldots$$

Taking k=3, and placing 18 poles in the generator, 18 coils are required (6 per phase), which can be connected in such a way that the fields linked by them can be added up.For this type of generator, 14 AWG cables will be used, since these sizes are thick enough to reduce ohmic losses, and at the same time, thin enough to be able to malleable them and make the coils.The cable chosen, 14 AWG, has a characteristic resistance of 8.286 mΩ/m at a temperature of 20ºC. To calculate the number of turns per coil, the following design equation is used to first determine the voltage per turn of the coil

$$V_c = 4.44\frac{p \cdot 60 \cdot RTS \cdot v}{120 \cdot 2 \cdot \pi \cdot r}B \cdot A$$

Where:

v: Voltage per coil loop.
p: Number of poles of the machine.
B: Maximum flow density through the coil.
A: Area of the magnet.
RTS: Reason for the tip speed.
v: Wind speed.
r: Wind turbine radius.

If you take 18 poles, an RTS of 5.5, a radius of 2.66 meters long, with a total flux density of 1.45 Wb/m² (corresponding to the case of 1 magnet disk in which each magnet provides 1.45 Wb/m²) and a magnet area of 700 x E-6 m2, you get:

$V_e = 37.28 \cdot v$

To calculate the number of turns per coil, the following constants are considered:

$l = 25$
rg = (8.26E-3)(0.2Ne)
xg = (4E-7)(700E-6)(14.67E-3)
$sin(\varphi) = 0.37$
$cos(\varphi) = 0.93$

Finally, considering a design that works for winds up to 10 m/s:

$V_{fn} = 6 \cdot N_c \cdot V_e \cdot (V_{desc}) - I(rg \cdot cos\varphi + xg \cdot sen\varphi)$

Substituting the corresponding values we have:

$110 = (6)\big((37.28\mathrm{E}-3)(10)\big) - 25((8.26\mathrm{E}-3)(0.2\mathrm{N}_c)(0.93) + (4\mathrm{E}-7)(700\mathrm{E}-6)(14.67\mathrm{E}-3)(0.37)$

Clearing the equation we obtain:

$N_e = 50\ turn/coil$

From the calculations the following is determined 18 poles were chosen, foreseeing a scheme of 6 coils per phase, and 18 coils in total and 50 turns per coil, this in order to take maximum advantage of generator space and the flow generated by all the magnets at all times, maximizing the use of space.Also with the help of AutoCAD®, the design of the casing, the arrangement of the magnets, the coil holder mass, the winding base and its main base were made. In Figures 1 and 2, drawings of the magnet arrangement and the winding base are shown.

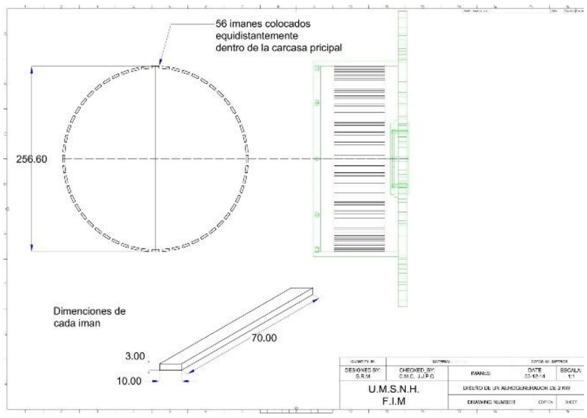

Figure 1. Magnet arrangement

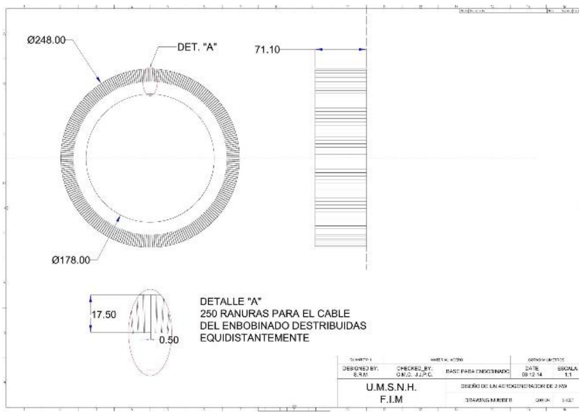

Figure 2. Winding base

V. CONCLUSION

By means of formulas it was possible to determine the characteristics of the generator winding to establish wire gauge and number of turns to generate 2 kilowatts with winds up to 10 m/s. With this generator design, we intend to put into practice the use of renewable energies in rural areas of our state and significantly reduce environmental damage, as well as achieve a significant impact on the improvement of the family economy of the inhabitants, in order to have energy sustainability and be able to implement local technologies.

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