

Control system based on fuzzy logic for the positioning of a wind turbine

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Abstract— The purpose of this research was to design a control system based on fuzzy logic for the positioning of a Windbelt wind turbine. In order to obtain a better use of the wind. The type of research was feasible and field project. The design is cataloged as experimental by the tests carried out on a prototype scale of a Windbelt wind turbine, the population is intentional non-probabilistic. The tests were carried out to guarantee the correct functioning according to the pre-established parameters. The control algorithm was implemented in a PIC18F452 microcontroller, in charge of exercising control over a servomotor according to the data obtained from the system, obtaining the positioning of the Winsbelt wind turbine with respect to wind gusts. The tests allowed the identification of some variables within the software that required scaling up in order to be compatible with the functioning of the other parts of the system.

Keyword - Keyword1, Keyword2, Keyword3, Keyword4, Keyword5

I. INTRODUCTION

Interest in all renewable energy sources has grown in recent years, due to the growing demand for electricity [1]. Three of the most used are photovoltaic, wind and hydroelectric [2]. In the case of wind energy, wind is the main source of energy, which occurs with greater incidence and constancy in some parts of the planet [3]. It is important to clarify that wind generators have advantages over other conventional energy sources, some of these are: indirect origin of the sun, which heats the air and causes wind, its continuous renewal, is inexhaustible, does not pollute and can withstand easily network electricity in remote sites and rural areas [4].

However, the generation of wind energy poses a series of challenges in the face of large-scale penetration [5]. Therefore, there is still work to be done to make it sufficiently reliable and "network friendly" in economically competitive terms [6]. This is mainly due to the uncertainty related to the wind, which puts the reliability and quality of the system at risk with the increasing penetration of this energy [7], and therefore, the main problems of network integration such as balance management and reserve capabilities may be questioned [8]. In this sense, several projects have been carried out that seek to produce this energy efficiently and at a low cost, as in the case of [9], where the suitability of a marine wind power plant scheme based on the elimination of the individual power converters of each wind turbine and the connection of a group of turbines to a single large power converter, through a centralized control.

Similarly, in [10], a hybrid wind / hydropower system is proposed with the objective of producing electricity at low cost. In the case of [11], a wind generator system consisting of a high-performance converter and a control unit based on a microcontroller that operates with a method that does not require knowledge of the optimum power characteristic or the measurement of wind speed and operates at a variable speed. In this sense, it must be taken into account that to generate electricity from the wind energy, it is necessary to use a mechanism that converts the kinetic energy of the air into some form of mechanical movement that is responsible for turning an electric generator [12].

Historically, this has been solved by the use of windmills, usually equipped with expensive shovels of tens of meters in length, however, this can change if the electricity is generated at lower cost by wind and without the need for a rotating element, using a device that harnesses the force of the wind to generate energy based on an aerodynamic phenomenon known as aeroelasticity [13]. An example of this is the Windbelt wind turbine, which is a micro-generator without moving parts that can provide small-scale power in a very efficient and low maintenance, it was designed to work in a static way, which is why it could lose efficiency, due to the behavior of wind gusts [14]. For the above, it seeks to improve its performance by providing movements similar to those of a traditional wind turbine, for which a controller is required to complete this task to achieve the objective efficiently.

In addition, the design of a control system based on fuzzy logic is proposed, because this is a methodology that provides a simple way to obtain a conclusion from inaccurate, noise or incomplete input information. A control based on fuzzy logic allows the conversion of linguistic control strategies, based on expert knowledge, into an automatic control strategy [15]. Thus, through the design of a control system, this research seeks to improve the performance of wind generators under normal operating conditions.

II. METHODOLOGY

The research was the feasible project type because it was oriented to provide answers or solutions to problems raised in a certain reality [16]. In this case, a control system is implemented to provide positioning to Windbelt wind turbine that could be implemented on the coast of La Guajira, where throughout the year there are constant wind currents due to the trade winds. Regarding the design, it was typified as experimental, because the variable under study is manipulated by the researcher in order to observe the results while trying to avoid other factors intervening in the observation [17].

A. Population and sample

The population was constituted by the wind turbines installed in the National Service of Learning (SENA) Regional Guajira, the sample is the Windbelt wind turbine, controlled by diffuse logic, in order to take advantage of the gusts of wind. In relation to the above, the sample is defined as intentional non-probabilistic [18].

B. Data collection instruments

For data collection, a technique similar to that of the signing was used, which is the folder system, which consists of a starting point in the analysis of the documentary sources through a general reading; documentary observation was applied because the research was based on texts, documents, journals, theses and articles, among others. According to [19], in documentary research it is necessary to introduce first of all those techniques related to the documentary analysis of bibliographic sources, which at the same time facilitate the writing of written work, as well as those operational techniques that allow the management of the documentary sources, therefore, for the elaboration of this research it was considered convenient to use techniques such as documentary observation and document registration.

The initial reading was followed by several more rigorous and slow readings, in order to extract the essential statements and logical aspects of their proposals and contents, to obtain useful data for the present investigation. Likewise, the development of this research was based on four phases of study necessary to achieve the design of a control system based on fuzzy logic for the positioning of a Windbelt wind turbine, as described below: a) documentary review, the Windbelt wind turbine operation was consulted in different information sources; b) definition of the system, a disc with absolute radial coding, a weather vane and its mechanical coupling and an optical system for reading the encoded disk; c) design and construction of the system, the control algorithm was designed, which ranges from the flow diagram of the controller, the design of the software to control the operation of the system in Unfuzzy, the equipment that met the requirements for the selected architecture, the fuzzy sets associated with the inputs and outputs were defined, and the fuzzy rules for the control of the system; d) validation, in this phase the operation tests of the positioning system were carried out.

III. RESULTS

A. Documentary review

The documentary review made it possible to define Windbelt wind turbine as a micro generator without moving parts that can provide electrical energy on a small scale in a very efficient way, this consists of a tape stretched between the ends of a frame of a non-ferrous material and at its ends has a set of magnets and coils, the magnets can move thanks to the vibrations generated by the movement of the tape when it is at the mercy of the wind, perform the reverse work of a speaker, generating electric energy [20]. To understand how the Windbelt wind turbine works, the example is the operation of a high voice, in which the electric current comes from an audio amplifier that goes through a coil that is attached to a cone of paper or cardboard, generating a magnetic field. This field interacts with that of a fixed magnet, generating forces that move the cone in one direction or another. The process used by the speakers to generate movement from electricity is reversible. This means that the movement of the coil with respect to a fixed magnet induces a current [21].

B. Definition of the system

In order to know the direction of the wind and translate this variable into degrees by supplying the Windbelt wind turbine position with respect to the wind gusts, a sensing system was designed that allows to obtain with precision the direction of the wind. For the design of the encoder disk, the data of the following encoder parameters table was used.

TABLE I. Parameters of the Encoder

Type of encoder	Binary Absolute Position
Bits	6
External diameter	12cm
Internal diameter	5cm
Pixels / Inch	2000

According to the previous table, the encoder has 64 possible positions in its 360 °, which means that the maximum error in the position is 5.6 °. Taking into account that the perimeter described by the generator is P = 251.32cm, the position error was calculated by a rule of three, and resulted in 3.9cm. As you can see, the maximum possible error is very small, but it is still possible to increase the resolution of the encoder to optimize its operation. Using the Codewheel software, it allowed coding a disk, which can be seen in Fig. 1 (Codewheel, 2008).

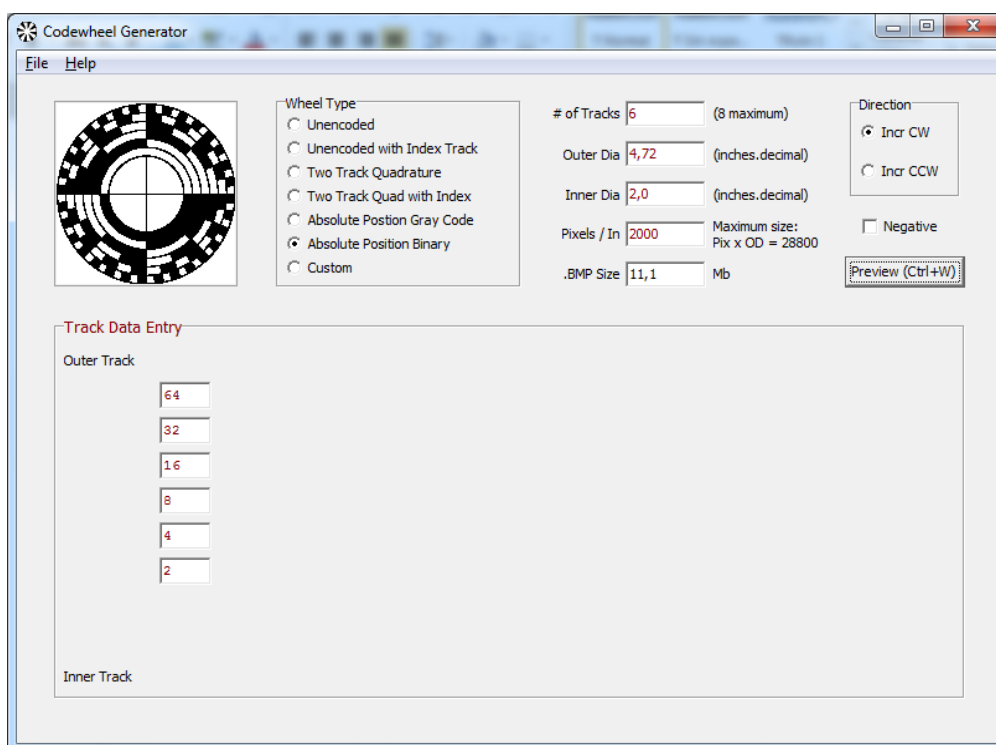


Fig. 1: Code Wheel Software for the Encoder design

The software provides the graphing of the parameters of the encoder disk, related to the internal and external diameter, number of tracks in (bits) and pixels per inch in the image. The parameters supplied is the binary absolute position encoder since no conversion is necessary to obtain its reading and fully meets the needs of this implementation without any error. In Fig. 2 you can see the designed disk.

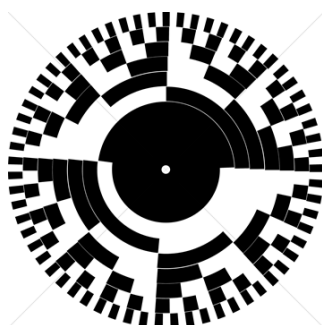


Fig. 2: Image of the Encoder Disk Generated by the Codewheel Software

Once the encoder was designed, it was printed in transparent acrylic by photographic process, this material offers quality and fidelity at the time of its reproduction. Subsequently, the process of gluing on a transparent plastic disc was carried out, which gives it the firmness so that it does not deform with speed (Fig. 3).



Fig. 3: Encoder disc fixed to the vane's neck.

To avoid an imbalance in its central axis, the weight of its tail and tip should be equal, although its areas exposed to the wind, this is done in order that the largest area is dragged by the wind (tail) and the point, point to the direction from which the wind comes. In this sense, taking into account that the vane will interact with the force of the wind, the materials used for its construction should be light to allow a movement with very low currents.

TABLE II. Parameters of the Encoder

Mast	Aluminum
Tail	Bakelite
Tread	DC motor without rotor, stator and magnets

With respect to the mast, it is composed of both the vertical axis and the horizontal bar where the pointer and the tail of the vane are supported. The vertical mast has a length of 25 cm, in its lower part is attached to the bearing system, which provides a minimum friction in this way allowing it to rotate with wind speeds less than 2 m/s. The horizontal mast has a length of 30cm and its function is to support the tail and the tip of the vane. This bar is connected to the vertical mast at its center where the tail and tip are located as shown in Fig. 4.



Fig. 4: Vertical and horizontal masts of the vane

The system responsible for reading the absolute position of the encoder disk was obtained through the use of infrared barriers, made up of as many transmitters and receivers as resolution bits (tracks), for which the use of 6 pairs of infrared LED diodes was chosen (IRLED) with its respective phototransistor (Fig. 5). Physically the IRLEDs are located in the lower part of the encoder at a distance of 3mm from the disk and in turn the phototransistors in the upper part of the disk at the same distance, in such a way that the six pairs corresponding to the sensor each act on one of the six tracks of the disc. In this way, the readings are performed radially starting from position one to sixty-four.

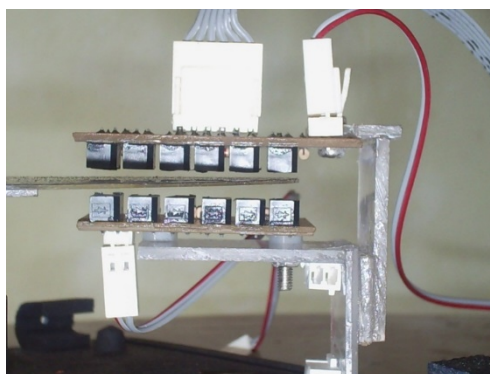


Fig. 5: Phototransistor and IRLED Array

C. Design and construction of the system

In this phase, the system was designed and built, firstly the flow diagram of the control system controller is shown, which sequentially shows the tasks and processes that must be performed (Fig. 6).

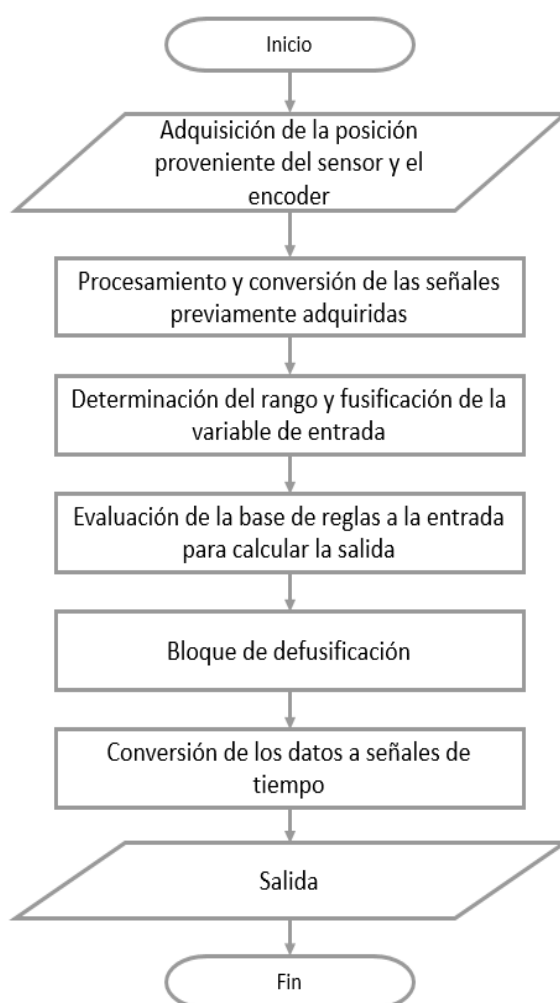


Fig. 6: Flow Diagram of the Control System Controller

The software for the control system was designed based on the electronic control circuit and the UNFUZZY software, designed by engineer Oscar G. Duarte, of the National University of Colombia, was used. The control algorithm starts with the declaration of the input variable (Fig. 7) (Duarte, 2008) called Position in this case, then its parameters are defined and upon entering the software UNFUZZY generates a code in the C language.

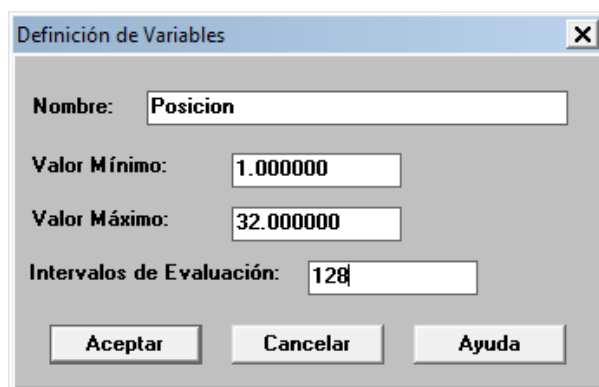


Fig. 7: Parameters of the Input Variable

Regarding the interface that allows the control logic to be applied to the windbelt wind turbine, in the prototype, the data link operates within an individual connection, managing the transmission of data so that the bits are sent without error, using a standard protocol that allows the synchronization between the transmitter and the receiver controls the flow of data bits, detecting transmission data errors. It is a protocol that operates at the data link level and offers reliable communication between the transmitter and the receiver, the connections between the microcontroller, the sensed system and the actuator were made through a serial data bus.

D. Validation

A fuzzy set is defined as: "A class of objects with continuous degrees of belonging (Zadeh, 1965). Such a set is characterized by a membership function (characteristic) which assigns to each object a degree that varies between zero and one. According to this definition, a diffuse set is composed of two essential parts: its elements and the function of belonging that it assigns to the degree of belonging to these elements as a whole. Once you have the defined variable, you proceed to fill the input universe, which is composed of 32 sets and singleton type diffuser, which is optimal for the system to be implemented, as well as simplifying the input merge process (Fig. 8) (Duarte, 2008).

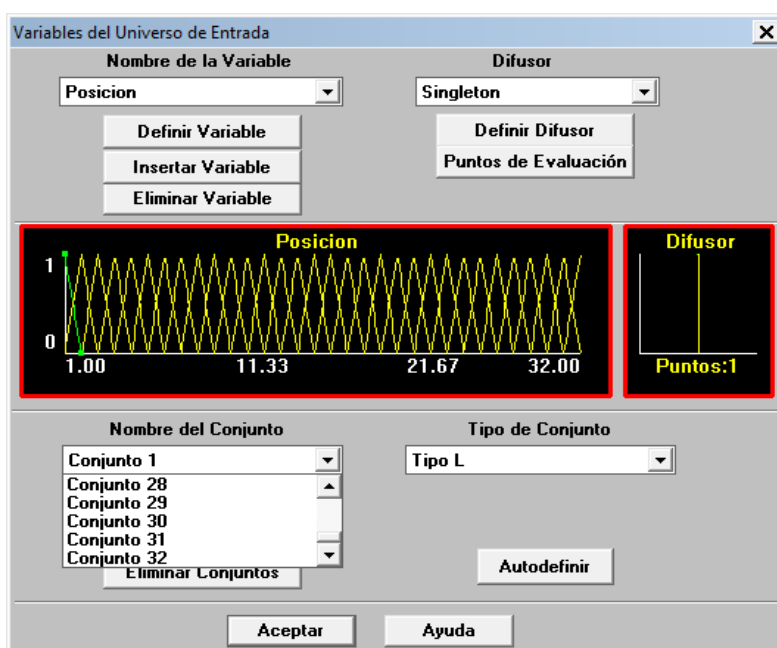


Fig. 8.:Definition of the Input Universe

The input universe is composed of 32 sets, once this data were defined, the output universe was defined with the desired range. In Fig. 9, the parameters of the output variable can be observed and in Fig. 10, the definition of the sets is shown (Duarte, 2008).

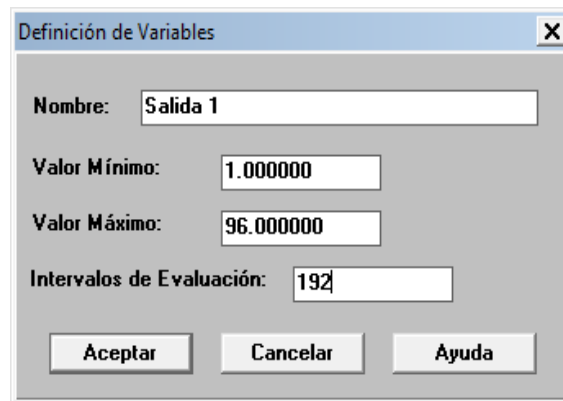


Fig. 9: Parameters of the Output Variable

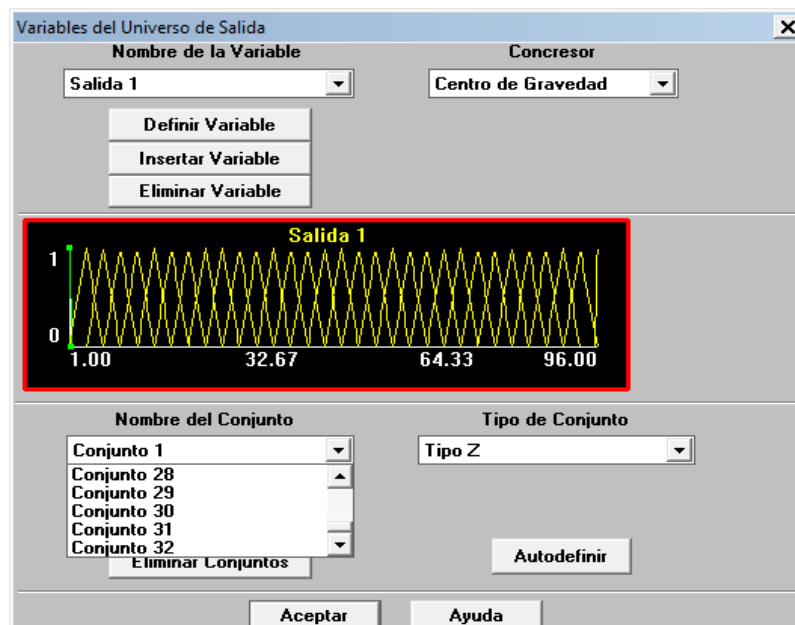


Fig. 10: Definition of the Universe of Exit

The universe of output in turn is also composed of 32 sets. Subsequently the definition of the base of rules is made, which must be added one by one (Fig. 11) (Duarte, 2008).

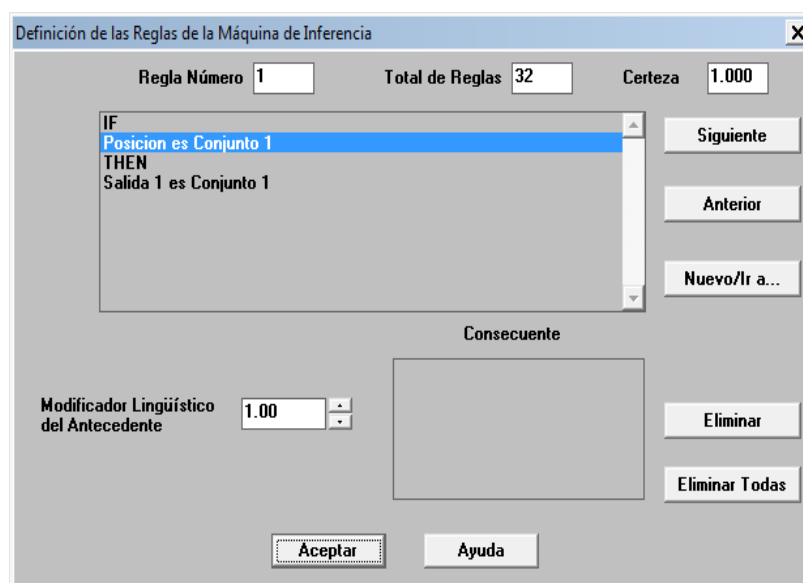


Figure 11. Definition of the Rule Base

With the parameters entered, the UNFUZZY software generates a code in the C language, which is extensive and in this state it is impossible to be implemented in a microcontroller, which is why the control program is compiled in the Basic language with the purpose of introducing it to the microcontroller.

IV. CONCLUSION

Due to the limitations of the microcontroller it is presented that the processing of the input signal takes approximately 2 to 8 seconds to produce an output value. Despite the limitation found, it is considered that the most significant contribution generated by this implementation has to do with the great improvements provided by the use of fuzzy logic in wind power generation systems forged by vibration, both in the use of wind turbines, as in the saving of resources in the positioning of the same, in addition to allowing to take advantage of the highest incidence of wind at all times.

When constructing the prototype that meets the technical conditions for controlling the position of the generator, there were some operational weaknesses, especially in the way the servo motor operates, which, when performing abrupt movements, shows deficiency due to the size of the structure and the inertia that wins with the movements, resulting in an overexertion for the coupling.

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