FRACTAL EFFECTS OF TEMPERATURE (ONSHORE-OFFSHORE): POWER LAWS, CROSSOVER PHENOMENON AND LONG-RANGE CORRELATIONS AND WIND POTENTIAL DEVELOPMENTS

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Abstract: With the intense demand for alternative energy matrices in the world and with regard to wind energy, the study has the objective of analyzing the time series of temperature in different regions, through the use of the DFA (Detrended Fluctuation Analysis) to verify the existence of power laws to analyze the temperature persistence of the studied regions. Thus, it is necessary to evaluate the temperature behavior in the wind speed, identify the existence of the offshore/onshore crossover phenomenon, propose temperature influences on the wind potential and, identify impacts of the proposed research on the circular economy. Preliminary results indicate the fractalized behavior of temperature in the prospected regions as well as the existence of the crossover phenomenon, which corroborates the existence of local wind potential.

Keywords: Temperature; Wind Energy; Crossover Phenomenon; DFA; Fractalization.

FRACTALIZAÇÃO DA TEMPARATURA: LEIS DE POTÊNCIA, FENÔMENO DO CROSSOVER E CORRELAÇÕES DE LONGO ALCANCE E DESDOBRAMENTOS NO POTENCIAL EÓLICO

Resumo: Com a intensa demanda por matrizes alternativas de energia no mundo, e no que tange à energia eólica, o estudo tem como objetivo analisar as séries temporais da temperatura (Onshore-Offshore), através do uso do DFA para verificar a existência de leis de potência para analisar a persistência de temperatura nas regiões estudadas. Assim, é necessário avaliar o comportamento da temperatura na velocidade do vento, identificar a existência do fenômeno crossover offshore/onshore, propor influências da temperatura no potencial eólico e identificar impactos da pesquisa na economia circular. Resultados preliminares indicam o comportamento fractalizado da temperatura nas regiões prospectadas, bem como a existência do fenômeno do crossover, o que corrobora a existência de potencial eólico local.

Palavras-chave: Temperatura; Energia Eólica; Fenômeno do Crossover; DFA; Fractalização.

1. INTRODUCTION

With urban and industrial growth, the energy demand has increased, consequently, the increase in the emission of pollutants into the atmosphere, climate change and the energy crisis have become evident. Contrary to this process, renewable energy sources and their use as a source of generation, progressively increase in the current world scenario [1]. Thus, the use of this type of energy has become something more recurrent and interesting from an economic, environmental and, social point of view, due to it is potential to promote less risk to the environment.

Due to the concept of sustainability primarily created, the idea of using natural resources to satisfy production demands without compromising future generations began to be discussed among nations. Given this, means that should be able to integrate social, energy, economic and environmental issues began to be thought. Faced with such indicators, the United Nations (UN) started the planning of the SDGs - Sustainable Development Goals - where among 17 goals is the 7th of "Affordable and clean energy" that aims to effect the energy transition from non-renewable sources to renewables, with attention to the reduction of pollution. In addition to objective number 12 “Responsible consumption and production”, which aims to substantially reduce waste generation through the Circular Economy. In this way, it is possible to connect the two objectives described in the subject of renewable energies [2].

In this way, a local and global scenario is formed where renewable energies and their integration processes represent a consolidation of the change in the energy paradigm and as such, it is necessary to know the variables associated with it, and, in this case, the temperature is one of them [3], because the knowledge of the behavior of these variables allows a benefit to society in the short, medium and long period.

Thus, taking into account that the wind turbines propellers are moved thanks to the force of the winds and that the models to be used in a given enterprise are defined in function of the wind potential of the implantation site, it can be said, therefore, that the winds are what most determine the use of wind power and these, in turn, are strongly influenced by the temperature in the region and its scale behavior, already mentioned [4]

Thus, understanding the dynamics of important variables, such as the temporal evolution of the temperature of a region, which is closely related to wind energy and meteorology, is a subject of great interest as already discussed [5].

However, in order to consolidate the insertion of electric energy in a given generation matrix, its prediction becomes necessary, which in the case of the wind matrix unfolds in the need for prior knowledge of the temperature and thus of the behavior of the winds, in particular its speed, as it is directly related to the generated power [6].

Therefore, with the above information, the general objective of this research is the analysis of the time series of temperature (Onshore-Offshore) through anemometers present in ocean buoys and stations from different locations, in the territories of North, Central, and South America, as well as the Europe and Asia, using the DFA (Detrended Fluctuation Analysis) technique to verify the existence of long-range correlations and associated power laws.

Finally, the specific objectives of this research is evaluate, with the DFA technique, the behavior of temperature in wind speed, identify the existence, or not, of the offshore/onshore crossover phenomenon and it is eventual dependencies, propose temperature influences on wind potential and, identify impacts of the proposed research on the circular economy.

2. METHODOLOGY

2.1 The DFA technique

In this study, the DFA (Detrended Fluctuation Analysis) method was used to analyze the data from the anemometers and investigate the existence of possible correlations between them. This technique has already been used in research on the dynamics of gene sequences [7], the behavior of heartbeat intervals [8] and the multifractal analysis of precipitation in coastal areas [9]. With this method, therefore, it becomes possible to evaluate non-stationary time series and verify the presence of long-range correlations.

Thus, it is worth considering that to carry out a DFA analysis, four steps must be followed: i) from the original series, the accumulated series is obtained; ii) divide the accumulated series into windows or subsets of size s; iii) remove the local trend in each window through a polynomial fit; and iv) calculate the float function F'(s) in terms of window sizes [7-11].

Thus, this method is primarily based on calculating and graphically representing the accumulated series, similar to a moving average of the data obtained in relation to the time interval of the series, since it is impossible to make a clear analysis from the raw data [7]. For a time series of total length k=1,2,3…N, for example, this moving average can be calculated by calculating the difference between the data obtained for each time instant t and the arithmetic mean of all the data.

$$MM(k) = \sum_{t=1}^{k} x(t) - \bar{x} \quad (1)$$

The arithmetic mean x, in turn, is calculated as follows:

$$\bar{x} = \frac{1}{N} \times \sum_{t=1}^{N} x(t) \quad (2)$$

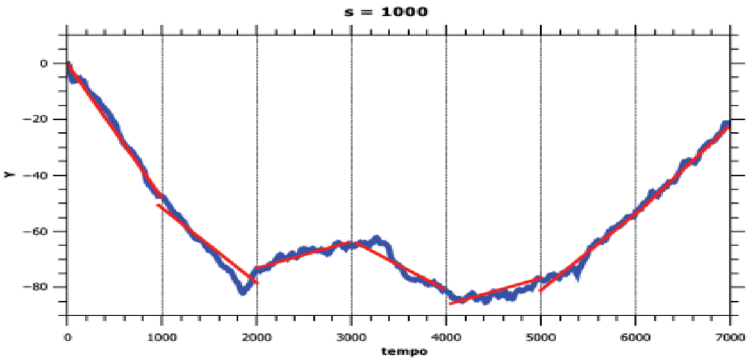
After performing these operations for each possible instance of the time series, a graph can be drawn from the results obtained that can be better analyzed in comparison with the graphical representation of the original time series, as shown in Figure 1.

Therewith, the time series is subdivided into a certain number (n) of nonoverlapping time segments of length s. Then, the method of least squares is used to calculate a linear fit for the data of each interval separately, thus determining the local trend of the function, that is, the behavior of the function in each of these windows.

The least-squares method, in turn, consists of determining a function (in the case studied, a first-degree function) for which the sum of the distance between the points obtained by the samples and the line itself is the smallest possible.

The least-squares method is a statistical way of evaluating regression analysis to approximate the solution of overdetermined systems [12].

Figure 1. Linear fits for s = 1000.



Afterwards, the function of the accumulated series, calculated previously, must be subtracted by the function of the local tendency found, obtaining a function that will be called W (k) s.

$$W(k) = MM(k) - Y_n(k) \tag{3}$$

Thus, it is possible to analyze the "detrended" series, with the fluctuation functions $F_s(n)$, calculating its variance.

$$F_s^2(n) = \sum_{t=1}^{s} W_s(k)[(n-1)s + k] \tag{4}$$

From this equation, one can calculate the average fluctuation function of the time series for the total length N, that is, the total length of all established segments.

$$F(n) = \sqrt{\frac{1}{N} \times \sum_{n=1}^{N} F_s^2(n)} \tag{5}$$

F(n) is the fluctuation function that gives the average rate of fluctuation of each quantity of the series comparing it with the average of the series, this gives the rate of fluctuation that each value of the series has in relation to the global average of the series.

This equation for the fluctuation can be rearranged as follows:

$$F(n) = \sqrt{\frac{1}{N} \times \sum_{k=1}^{N} [MM(k) - Y_n(k)]^2} \tag{6}$$

Next, it is necessary to repeat this procedure using another scale, that is, adopting other values for the length s of the series segments [7].

A logarithmic scale graph is drawn up for the mean fluctuation values for each analyzed scale and, finally, a linear adjustment in the form Y = ax +b. Thus, it is possible to formulate a table, specified below, to identify the behavior of the time series.

Table 1. Characterizations of the Hurst Exponent.

α Values	**Series Characterization**	**Behavioral Description**
$0 < \alpha < 0.5$	Anti-persistent Behavior	Low values tend to be followed by high values and vice versa
$\alpha \cong 0.5$	Random Behavior	There is no correlation in their values

α Values	Series Characterization	Behavioral Description
$0.5 < \alpha < 1$	Persistent Behavior	High/low values tend to be followed by high/low values
$\alpha \geq 1$	Anti-persistent Behavior	When α<3/2, there is a subdiffusive behavior
		When α = 3/2 there is a diffusive behavior
		When α> 3/2 there is a super-diffusive behavior

The α present in the fit equation is called the Hurst exponent, and from its numerical value, it is possible to characterize the behavior of the series.

2.2 The use of the DFA technique in temperature analysis

For the analysis of temperature, the DFA technique was then used on data taken from anemometers located in different locations in the Americas and the oceans, and found at different altitudes, although most of them are located at levels close to the level of the sea [13-15].

3. RESULTS AND DISCUSSION

From this study, it is intended to have an analysis of the issue of temperature concerning the behavior of the winds with the DFA for other coastal, oceanic and, continental regions of the planet with data ballast, numerical series, collected in buoys and international collection stations. through a program to which Brazil is a loyal signatory, to mention the PIRATA (Prediction and Research Moored Array in the Tropical Atlantic) and the PNBOIA (National Buoys Program). Thus, it is possible to identify world regions that may have better performance in the application of wind turbines.

It is also expected, through the analysis of the temperature of regions, to identify patterns of temperature behavior and power laws associated with the dynamics of winds at different scales and under different geographic, climatic and orographic conditions.

In this way, therefore, it is intended to consolidate the DFA technique as a methodology to determine, with predictability and reliability, the wind energy generation potential of a given location.

Thus, considering the objectives of the project, in addition to the data collected and treated primarily in the meteorological stations of Bahia for an analysis of the viability of the research, very promising results are recorded in the sense of corroborating the existence of fractalized behavior of temperature, before only found for wind speed.

In this way, at first, it was identified that there is no relationship between the relief of the regions and their temperature, since some anomalies presented in some stations, such as the amount of crossovers, do not occur in others of the same relief. In addition, it was thought about the possible influence of the South Atlantic Anomaly with the amount of crossovers present in the cities, but the regions presented great differences between them and the anomaly is "uniform" in Bahia, so for there to be a correlation, the data from the stations from Bahia should be similar.

4. CONCLUSION

In view of all the data presented regarding the correlation of temperature with the developments in wind potential, it was possible to determine that the methodology applied in the research is feasible to identify the persistence, or not, of the temperature in a given region

It is recorded that the objectives are being met and it is evident that data from other regions are still under analysis with indications that this is a generalized behavior. Finally, it is possible to increase the theme about of Circular Economic in the nations, as well to make better use of natural resources, with the use of the method presented in this research wind turbines will be more efficient because they are located in areas conducive to good energy generation. However, it is expected in future studies the objective applicability of the research and reuse of the analyzes brought in this work, as it will be possible to generate more efficient and usual wind energy in the environments that are conducive to it.

Acknowledgments

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5. REFERENCES

[1] FORTES, Márcio Zamboti et al. **SMART CITY–UMA OPORTUNIDADE DE APLICAÇÃO DE PEQUENOS SISTEMAS GERADORES COM ENERGIA RENOVÁVEL**. ABM Week, 2015.

[2] Farias, Marta Emília Aires Cavalcante; Martins, Maria; Cândido, Gesinaldo Ataíde, 2021. Agenda 2030 e Energias Renováveis: Sinergias e Desafios para Alcance do Desenvolvimento Sustentável. **Research, Society and Development**, V. 10, N. 17, P. E13101723867-E13101723867.

[3] Manwell, James F.; Mcgowan, Jon G.; Rogers, Anthony L, 2010. **Wind Energy Explained: Theory, Design and Application**. John Wiley & Sons.

[4] Lira, Marcos Antonio Tavares; Neto, José Machado Moita; Loiola, João Victor Lopes; Silva, Emerson Mariano; Alves, José Maria Brabo, 2017. Caracterização do Regime de Ventos no Piauí para o Aproveitamento de Energia Eólica. **Revista Brasileira De Meteorologia**, V. 32, P. 77-88.

[5] Borja, M. A.; Jaramillo, O. A, 2004. **Wind Speed Analysis in La Ventosa, Mexico**: A Bimodal Probability Distribution Case. Renewable Energy V. 29 P. 1613-1630.

[6] Hansen, Anca, 2008. **Modeling and Control of Variable-Speed Multi-Pole Permanent Magnet Synchronous Generator Wind Turbine.** Wiley Interscience.

[7] PENG, C.K.; BULDYREV, S.V.; HAVLIN, S.; SIMONS, M.; STANLEY, H.E.; GOLDBERGER, A.L**. Mosaic organization of DNA nucleotides**. Physical Review E. 1994.

[8] IVANOV, P.; ROSENBLUM, M.G.; PENG, C.K.; MIETUS, J.; HAVLIN, S.; STANLEY, H.E.; GOLDBERGER, A.L. **Scaling behavior of heartbeat intervals obtained by wavelet-based time-series analysis**. Nature. 1996.

[9] BARRETO, I.; STOSIC, T. **Multifractal analysis of rainfall in coastal area in Pernambuco, Brazil**. Federal Rural University of Pernambuco, Brazil, feb. 2021.

[10] LACZKOWSKI, Ivan Marcelo; LACZKOWSKI, Mirian Sousdaleff. **APLICAÇÃO DO MÉTODO DFA NA IDENTIFICAÇÃO DE CORRELAÇÕES E FRACTALIDADES EM SÉRIES TEMPORAIS SONORAS**. EPCT, Campo Mourão, 21 oct. 2013.

[11] BULDYREV, S. V.; GOLDBERGER, A. L.; HAVLIN, S.; MANTEGNA, R. N.; MATSA, M. E.; PENG, C. K.; SIMONS, M. and STANLEY, H. E. **Long-range correlation-properties of coding and noncoding DNA-sequences: Genbank Analysis**. Phys Rev E, v 5, 1995

[12] ABAZID, Mohammad; ALKOUD, Duaa. **A LEAST-SQUARES APPROACH TO PREDICTION THE FUTURE SALES OF PHARMACY**. Near East University, Nicósia, Chipre, jan. 2018.

[13] Santos, J. V. C; Moreira, D. M; Gonçalves, M. A. M. S, 2020. **Estudo das Características Espaciais e Temporais da Velocidade do Vento Utilizando a Técnica DFA e o Modelo WRF em Regiões do Estado da Bahia e no Oceano Atlântico Sul**. Salvador: Senai Cimatec.

[14] Santos, J.V.C; Moreira, D.M.; Moret, M.A.; Nascimento, E.G.S., 2019. **Analysis of Long-Range Correlations of Wind Speed in Different Regions of Bahia and the Abrolhos Archipelago**, Brazil. Energy. 167:680-687.

[15] Santos, J.V.C; Perini, N.B., Moret, M.A.; Nascimento, E.G.S.; Moreira, D.M., 2020. **Scaling Behavior of Wind Speed in the Coast of Brazil and the South Atlantic Ocean: The Crossover Phenomenon**. Energy.

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