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Lagrange Approximation between Generator's and Transformer's Parameters of Vau-Dejes Hydropower-plant

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***Abstract*— The objective of this paper consists in reflecting the tendency of transformer and generator's main parameters at Vau-Dejës hydropower plant's aggregate. The parameters taken into consideration are such as voltage and current of the generator, etc. These parameters are statistically set in front of the transformer's winding and oil temperature respectively.**

The parameters are set against each other and the relevant trend-line is extracted. We know that, the interpolation is the process of finding a polynomial that goes as much as exactly through some given points. In our study the Lagrange method is used whose algorithm is implemented in Matlab. Furthermore, we have implemented the ANOVA analysis as well as the multiple testing to verify the hypothesis of the fact that the bigger are the electrical parameters the higher is the temperature of the transformer.

Finally, the period during in which these data are derived from Vau-Dejes hydropower plant was summer. This means that, due to the summer season, the aggregate has not operated with full power due to lack of precipitation. Therefore, the convey energy from the generator to the transformer has been relatively low and this is reflected in the winding and oil temperature of the transformer.

Keywords—sample; oil; winding; Lagrange; Matlab; interpolation

I. INTRODUCTION

One of the main parts of a hydro-power plant is the electrical generator and the power transformers.

Generators are useful appliances that supply electrical power during a power outage and prevent discontinuity of daily activities or disruption of business operations. Generators are available in different electrical and physical configurations for use in different applications.

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction [12]. Commonly, transformers are used to increase or decrease the voltages of alternating current in electric power applications [3].

A varying current in the transformer's primary winding creates a varying magnetic flux in the transformer core and a varying magnetic field impinging on the transformer's secondary winding [18]. This varying magnetic field at the secondary winding induces a varying electromotive force (EMF) or voltage in the secondary winding. Making use of Faraday's Law in conjunction with high magnetic permeability core properties, transformers can thus be designed to efficiently change AC voltages from one voltage level to another within power networks [16].

ANOVA is a methodology that allows us to compare the averages of different groups (Boudreaux-Bartels. et al), in order to have more information. In fact there are many different types of ANOVA-s but we have addressed in detail one of them. This is called one-way ANOVA [16].

The ANOVA table was used to compare differences of medians between more than 2 groups. It accomplishes this by observing the change of the data and where this change is found. Specifically, ANOVA compares the sum of variation between groups with the sum of change within groups. It can be used for observational and experimental studies [2].

When we receive samples from a population, we expect that any median sample change easily because we are taking a sample instead of measuring the entire population; this is called a mistake, but we often refer unofficially to as the effect of "fortune". So, we always expect to have some changes in the medians between different groups (Stearns et al. 1996). The question is: is the difference between the groups larger than that expected to be caused by chance? In other words, is there likely to be a real authentication?

Although it may seem difficult at first, the statistics become much easier if we understand what kind of test is performed [17].

For the sake of correctness, let's explain variances parameters in the figure below:

Source	DF	SS	MS	F	P
Factor	2	2510.5	1255.3	93.44	0.000
Error	12	161.2	13.4		
Total	14	2671.7			

Fig 1.Example of ANOVA table

- **Source** means "the source of variation data". As it will be explained, the options available for a one-factor study, such as the study of learning, are:

factor, error and total. Factor is the characteristics that defines the population that is going to be compared.

- **DF** means “the freedom grades in the source”
- **SS** means “ the sum of the squares due to the source
- **MS** means “the median of the sum of the squares due to the source
- **F** means “the F statistics”
- **P** means “ the P value”

Now let us take in consideration the parameters below

- Factor means "the variability due to the interest factor." Sometimes, the factor is a treatment and therefore is marked as treatment. Also, sometimes it is marked between to clarify that the line is linked with the variability between groups
- **Error** means "variability within groups" or "the unexplained random error". Sometimes, it is marked as Within to make it clear that the line has to do with the variability within groups.
- **Total** means the “total variability in the data from the median”; so, avoiding the interest factor

The alternative hypothesis to one-way ANOVA is that at least one couple of the group average to be significantly different. We will use multiple-test in Matlab to test which couple is different.

To briefly explain the working principle of this test. We have shown shows the simulation results of the test manifold.

comp =
1.0000 2.0000 0.2948 0.4540 0.6132
1.0000 3.0000 0.4988 0.6580 0.8172
2.0000 3.0000 0.0448 0.2040 0.3632

The first two columns of the output represent the group numbers. This means that the first line compares the groups 1 and 2 and the bottom line compares groups 2 and 3. The third column and fifth end points of a 95% confidence interval and the fourth column is the resulting difference. So the difference in averages of group 1 and 3 is 0.6580 and the confidence interval for the difference is

[0.4988 , 0.8172].

The interval does not contain zero, and so we can conclude that this couple has a significant margin.
Also from this simulation we obtain even graphical output that will be treated in the next sections.
The goal of the paper consists in defining the trend of the data obtained from the Vau Dejes hydropower plant. These include the temperature of oil and winding of the transformer as well as the electrical parameters of the electrical generator. The structure of the paper begins with methodology used to make the Lagrange approximation. Then the results of this analysis are presented. Finally after showing and interpreting these results, the section of conclusion, recommendation and future work is treated.

II.METHODOLOGY AND DATA

In this study we have taken samples from the interval 14.07.2014 – 29.08.2014. So, for 47 days, every hour of the day for 20 consecutive hours of electrical parameters of the aggregate we have made the absorption of the data from the computer control room of the Vau Dejes hydropower plant. Then, for the data of each day, the mathematical average of these parameters is calculated. These parameters are:

- The generator voltage
- The generator current
- The active power of the generator
- The reactive of power generator
- The excitation voltage
- The excitation current
- The active power of the contactor
- The reactive power of the contactor

These electrical parameters of the aggregate are set in the depending of the temperature of the transformer oil and winding. The electrical parameters are variable and independent; the temperature of the winding and the oil of the transformer are constant and dependable from the electrical parameters. We know that the higher the values of these electrical parameters in the aggregate are, the greater is the temperature of the oil and winding in the transformer, but, a functional link does not exist. Consequently, the only way to find the dependence from each other is the statistical study. In this study we used Lagrange interpolation to find this dependence. Also to test the hypothesis in question we have implemented the one-way ANOVA and multiple testing in Matlab.

III.THE RESULTS OF THE SIMULATIONS

In this section we will look at the functional connections of the above mentioned electrical parameters of the generator of an aggregate versus the transformer’s temperature of winding and oil in that aggregate. Also we will treat and argue the Lagrange polynomial fitting, results of ANOVA table and multiple testing.
Let's look at the functional connectivity of the dependence of *the temperature of the winding and oil* of the transformer against the *voltage of generator* of the aggregate.

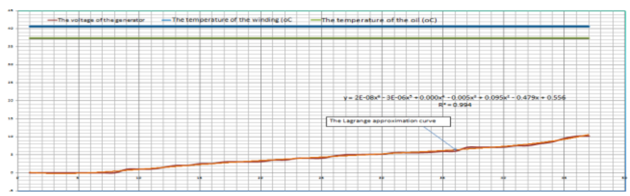

Fig 2. The graph that expresses the dependency between the temperature of the winding and the voltage of the generator and the curve of Lagrange polynomial.

In this figure we have shown the three graphs. The two straight lines represent the temperature of winding and the oil of the transformer and the next line consists in the curve of generator voltage as well as the Lagrange polynomial. The equation of this polynomial is:

$$y = 2*10^{-8}*x^6 – 3*10^{-6}-0.005*x^3-0.479*x + 0.556 \quad (1)$$

The coefficient of determination of the Lagrange fitting is **R^2=0.994.**
To test our hypothesis that consists in the fact that the higher are the electrical parameters the higher are the temperatures we will show the ANOVA table results as well as the multiple-test.

Let us observe the case in question. Below we have shown the ANOVA table and the graphical output from the simulations:

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	38243.9	2	19121.95	6388.89	9.64571e-137
Error	413	138	2.99		
Total	38656.9	140			

Fig 3. The ANOVA table

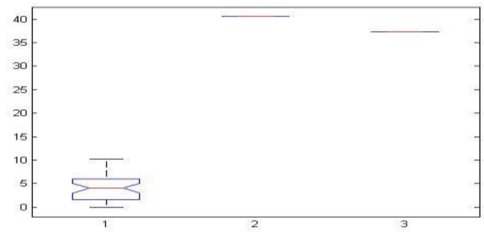

Fig 4. The graphical output from the Matlab simulation

As we explained above, the alternative hypothesis in one-way ANOVA is that at least one couple of the average of the groups must be significant different.
This is the graphical output from **anova1**. The sepal width was used for this analysis, and we see a notched box-plot of the three groups. There appears to be significant evidence that the **medians** between group) and the others are different because the notched intervals do not overlap.
The results of the ANOVA test are shown in the table. The second column is the sum of squares (SS); the third column is the degrees of freedom; and the fourth column is the mean of squares (SS/df). The observed value of the F-statistic and the corresponding p-value are also shown. The p-value is very small, so we have evidence that at least one pair of group means is significantly different.

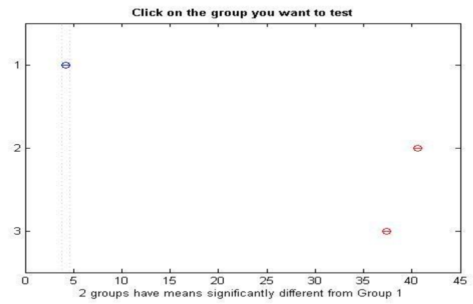

Fig 5. This figure the graphical output of the multiple testing. The circle shows the calculated average and the line consists in the credibility of 95% for the calculated average

TABLE I - The table generated from the multiple testing simulation in Matlab

1	2	-37.2799	-36.4435	-35.6071
1	3	-34.0399	-33.2035	-32.3671
2	3	2.4036	3.2400	4.0764

The interval **[-34.0399,-323671]** does not contain zero, and so we can conclude that this couple has a significant margin.
Let's look at the functional connectivity of the dependence of *the temperature of the winding and oil* of the transformer against the *current of generator* of the aggregate.

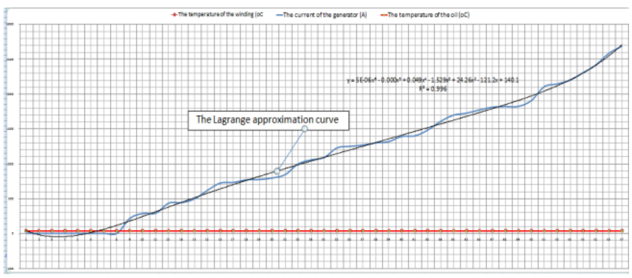

Fig 6. The graph that expresses the dependency between the temperature of the winding and the current of the generator and the curve of Lagrange polynomial.

In this figure we have shown the three graphs. The two straight lines represent the temperature of winding and the oil of the transformer and the next line consists in the curve of generator current as well as the Lagrange polynomial. The equation of this polynomial is:

$$y = 5*10^{-6}-0.049*x^4-1.529*x^3 +24.26*x^2-121.2*x+140.1 \quad (2)$$

The coefficient of determination of the Lagrange fitting is **R^2=0.996.**

Let us observe the graphical output of the ANOVA table and the multiple testing:

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	3.53862e+07	2	17693114.8	83.43	1.77012e-24
Error	2.92646e+07	138	212062		
Total	6.46508e+07	140			

Fig7. The ANOVA table

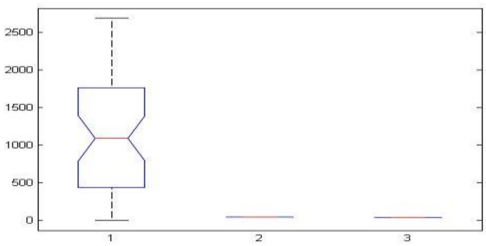

Fig 8. The graphical output from the Matlab simulation

This is the graphical output from **anova1**. The sepal width was used for this analysis, and we see a notched box-plot of the three groups. There appears to be significant evidence that the **medians** between one group and the others are different because the notched intervals do not overlap.
The results of the ANOVA test are shown in the table. The second column is the sum of squares (SS); the third column is the degrees of freedom; and the fourth column is the mean of squares (SS/df). The observed value of the F-statistic and the corresponding p-value are also shown. The p-value is very small, so we have evidence that at least one pair of group means is significantly different.

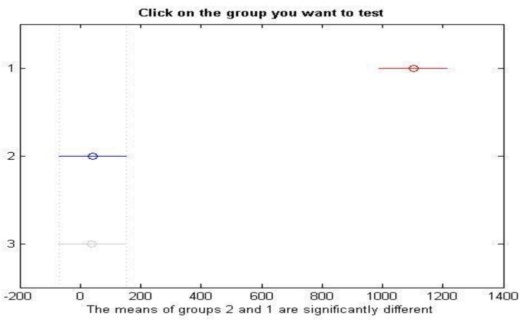

Fig 9. This figure the graphical output of the multiple testing. The circle shows the calculated average and the line consists in the credibility of 95% for the calculated average

TABLE II - The table generated from the multiple testing simulation in Matlab

1	2	0.8383	1.0611	1.2837
1	3	0.8417	1.0643	1.2870
2	3	-0.2194	-.0032	0.2259

The interval [0.8383, 1.2837] does not contain zero, and so we can conclude that this couple has a significant margin.

Let's look at the functional connectivity of the dependence of *the temperature of the winding and oil* of the transformer against the *active power of the generator* of the aggregate.

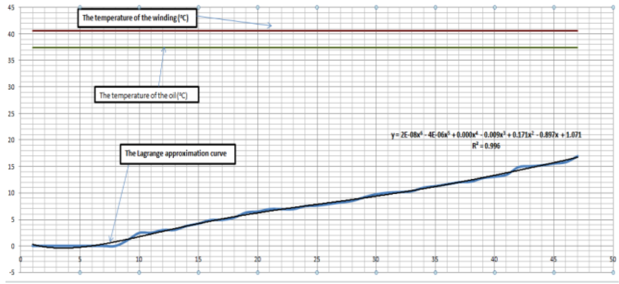

Fig 10. The graph that expresses the dependency between the temperature of the winding and the active power of the generator and the curve of Lagrange polynomial.

In this figure we have shown the three graphs. The two straight lines represent the temperature of winding and the oil of the transformer and the next line consists in the curve of generator active power as well as the Lagrange polynomial. The equation of this polynomial is:

$$y = 5*10^{-0.8}x^{6}-7*10^{-0.6}*x^{5}-0.013*x^{3}+0.24*x^{2}-1.191*x+1.28 \quad (3)$$

The coefficient of determination of the Lagrange fitting is $\mathbf{R^2=0.996}$.
Let us observe the graphical output of the ANOVA table and the multiple testing:

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	16403.2	2	8201.6	169.45	6.92619e-38
Error	6679.5	138	48.4		
Total	23082.7	140			

Fig11. The ANOVA table

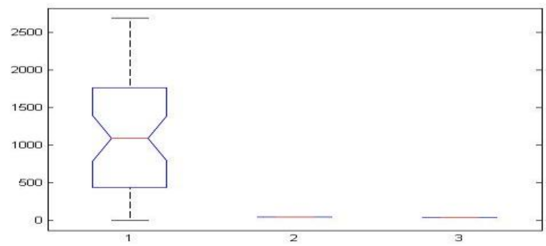

Fig 12. The graphical output from the Matlab simulation

This is the graphical output from **anova1**. The sepal width was used for this analysis, and we see a notched box-plot of the three groups. There appears to be significant evidence that the **medians** between one group and the others are different because the notched intervals do not overlap.

The results of the ANOVA test are shown in the table. The second column is the sum of squares (SS); the third column is the degrees of freedom; and the fourth column is the mean of squares (SS/df). The observed value of the F-statistic and the corresponding p-value are also shown. The p-value is very small, so we have evidence that at least one pair of group means is significantly different.

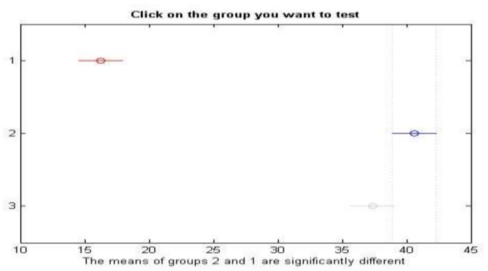

Fig13. This figure shows the graphical output of the multiple testing. The circle shoes the calculated average and the line consists in the credibility of 95% for the calculated average

TABLE III - The table generated from the multiple testing simulation in Matlab

1	2	0.4395	1.9433	1.5364
1	3	0.3446	1.3556	1.2346
2	3	-0.3633	-0.3632	0.4543

The interval [1.3556, 1.2346] does not contain zero, and so we can conclude that this couple has a significant margin.

Let's look at the functional connectivity of the dependence of *the temperature of the winding and oil* of the transformer against the *reactive power of the generator* of the aggregate.

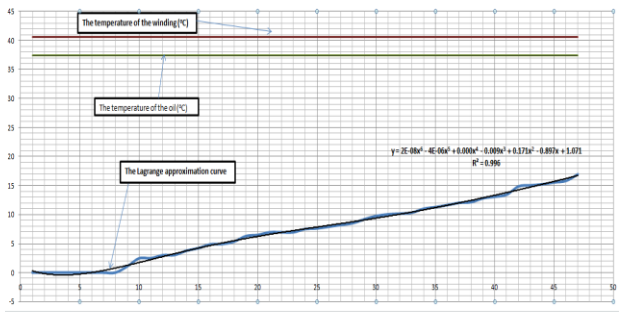

Fig 14. The graph that expresses the dependency between the temperature of the winding and the reactive power of the generator and the curve of Lagrange polynomial.

In this figure we have shown the three graphs. The two straight lines represent the temperature of winding and the oil of the transformer and the next line consists in the curve of generator reactive power as well as the Lagrange polynomial. The equation of this polynomial is:

$$y = 2*10^{-0.8}*-4*10^{-0.6}-0.009*x^3+0.171*x^2-0.897+1.071 \quad (4)$$

The coefficient of determination of the Lagrange fitting is $\mathbf{R^2=0.996}$.

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	31443.1	2	15721.6	1757.83	6.6587e-99
Error	1234.2	138	8.9		
Total	32677.4	140			

Let us observe the graphical output of the ANOVA table and the multiple testing:

Fig15. The ANOVA table

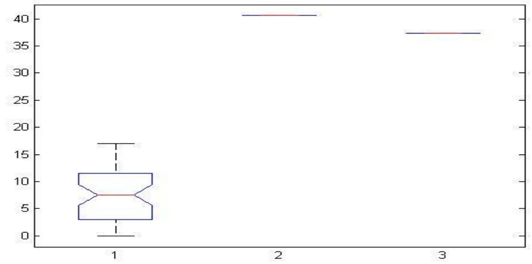

Fig 16. The graphical output from the Matlab simulation

This is the graphical output from **anova1**. The sepal width was used for this analysis, and we see a notched box-plot of the three groups. There appears to be significant evidence that the **medians** between one group and the others are different because the notched intervals do not overlap.

The results of the ANOVA test are shown in the table. The second column is the sum of squares (SS); the third column is the degrees of freedom; and the fourth column is the mean of squares (SS/df). The observed value of the F-statistic and the corresponding p-value are also shown. The p-value is very small, so we have evidence that at least one pair of group means is significantly different.

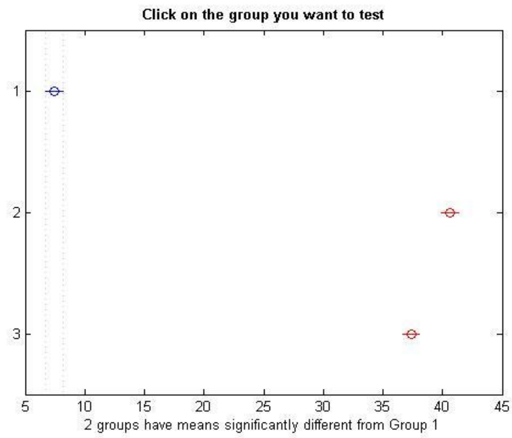

Fig17. This figure shows the graphical output of the multiple testing. The circle shoes the calculated average and the line consists in the credibility of 95% for the calculated average

TABLE IV - The table generated from the multiple testing simulation in Matlab

1	2	3.2036	3.3011	3.3985
1	3	3.2033	3.3007	3.3982
2	3	-0.0978	-0.003	-0.0971

The interval [3.2036, 3.3985] does not contain zero, and so we can conclude that this couple has a significant margin.
Let's look at the functional connectivity of the dependence of *the temperature of the winding and oil* of the transformer against the *excitation voltage of the generator* of the aggregate.

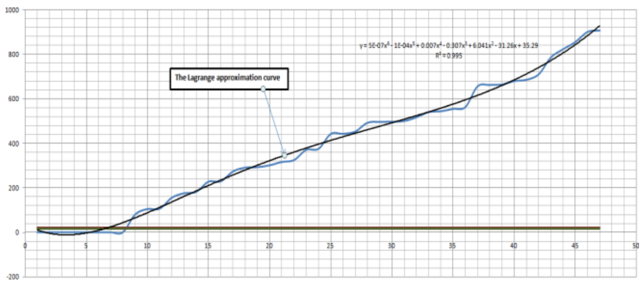

Fig 18 - The graph that expresses the dependency between the temperature of the winding and the excitation voltage of the generator and the curve of Lagrange polynomial.

In this figure we have shown the three graphs. The two straight lines represent the temperature of winding and the oil of the transformer and the next line consists in the curve of excitation voltage as well as the Lagrange polynomial. The equation of this polynomial is:

$$y = 5*10^{-0.7}*x^6-10^{0.4}*x^5+0.07*x^4-0.307*x^3+6.041*x^2-31.26*x+35.29 \quad (5)$$

The coefficient of determination of the Lagrange fitting is **R^2=0.995.**
Let us observe the graphical output of the ANOVA table and the multiple testing:

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	12602.3	2	6301.13	10.79	4.44567e-05
Error	80624.8	138	584.24		
Total	93227	140			

Fig 19 – The ANOVA table

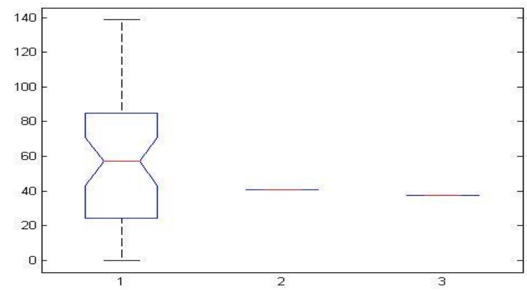

Fig 20. The graphical output from the Matlab simulation

This is the graphical output from **anova1**. The sepal width was used for this analysis, and we see a notched box-plot of the three groups. There appears to be significant evidence that the **medians** between one group and the others are different because the notched intervals do not overlap.
The results of the ANOVA test are shown in the table. The second column is the sum of squares (SS); the third column is the degrees of freedom; and the fourth column is the mean of squares (SS/df). The observed value of the F-statistic and the corresponding p-value are also shown. The p-value is very small, so we have evidence that at least one pair of group means is significantly different.

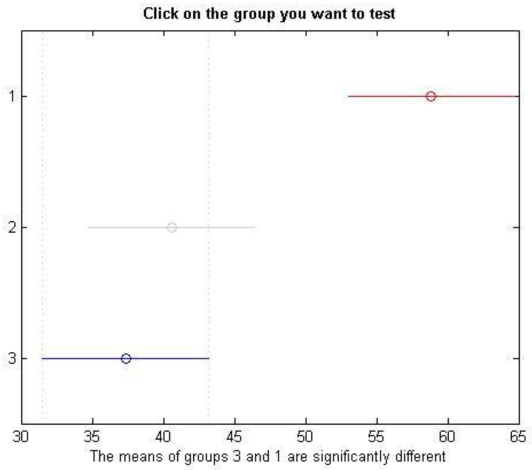

Fig 21. This figure shows the graphical output of the multiple testing. The circle shoes the calculated average and the line consists in the credibility of 95% for the calculated average

TABLE IV - The table generated from the multiple testing simulation in Matlab

1	2	6.5517	18.2377	29.9236
1	3	9.7917	21.4777	33.1636
2	3	-8.4459	3.2400	14.9259

The interval [6.5517, 29.9236] does not contain zero, and so we can conclude that this couple has a significant margin.
Let's look at the functional connectivity of the dependence of *the temperature of the winding and oil* of the transformer against the *excitation current of the generator* of the aggregate.

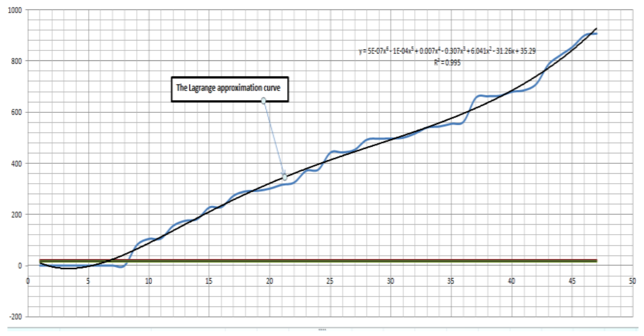

Fig 22 - The graph that expresses the dependency between the temperature of the winding and the excitation current of the generator and the curve of Lagrange polynomial.

In this figure we have shown the three graphs. The two straight lines represent the temperature of winding and the oil of the transformer and the next line consists in the curve of excitation current as well as the Lagrange polynomial. The equation of this polynomial is:

$$y = 5*10^{-0.6}*x^6-5*10-^{0.4}*x^5+0.19*x^4-0.468*x^3+6.041*x^2-87.45*x+38.50 \quad (6)$$

The coefficient of determination of the Lagrange fitting is $\mathbf{R^2=0.995}$.
Let us observe the graphical output of the ANOVA table and the multiple testing:

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	4.25074e+06	2	2125372.4	84.43	1.13124e-24
Error	3.47406e+06	138	25174.4		
Total	7.72481e+06	140			

Fig 23 – The ANOVA table

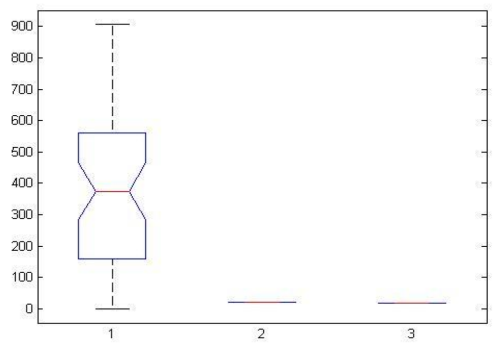

Fig 24. The graphical output from the Matlab simulation

This is the graphical output from **anova1**. The sepal width was used for this analysis, and we see a notched box-plot of the three groups. There appears to be significant evidence that the **medians** between group and the others are different because the notched intervals do not overlap.
The results of the ANOVA test are shown in the table. The second column is the sum of squares (SS); the third column is the degrees of freedom; and the fourth column is the mean of squares (SS/df). The observed value of the F-statistic and the corresponding p-value are also shown. The p-value is very small, so we have evidence that at least one pair of group means is significantly different.

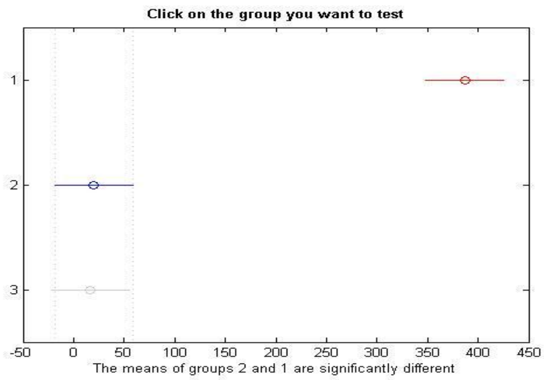

Fig 25. This figure shows the graphical output of the multiple testing. The circle shoes the calculated average and the line consists in the credibility of 95% for the calculated average.

Let's look at the functional connectivity of the dependence of *the temperature of the winding and oil* of the transformer against the *active power of the contactor* of the aggregate.

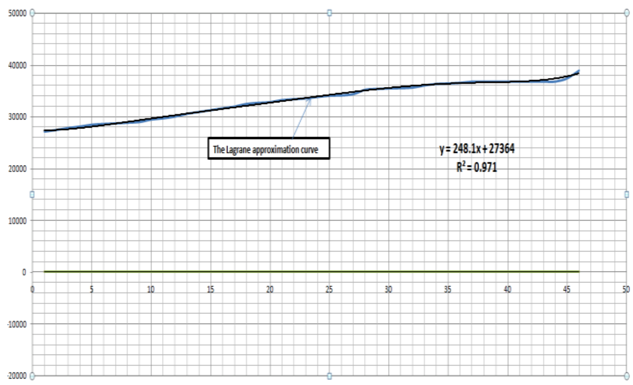

Fig 26 - The graph that expresses the dependency between the temperature of the winding and the active power of the contactor and the curve of Lagrange polynomial

In this figure we have shown the three graphs. The two straight lines represent the temperature of winding and the oil of the transformer and the next line consists in the curve of active power of the contactor as well as the Lagrange polynomial. The equation of this polynomial is:

y = 248.1*x+27364 (6)

The coefficient of determination of the Lagrange fitting is $\mathbf{R^2=0.971}$.

Let us observe the graphical output of the ANOVA table and the multiple testing:

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	3.41406e+10	2	1.70703e+10	4201.55	2.38355e-124
Error	5.60674e+08	138	4.06286e+06		
Total	3.47012e+10	140			

Fig 27 – The ANOVA table

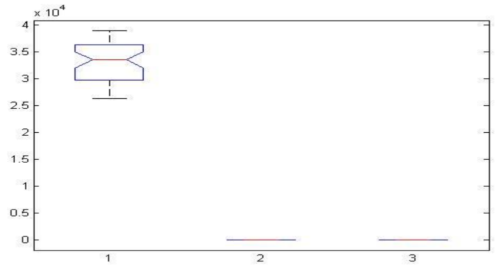

Fig 28. The graphical output from the Matlab simulation

This is the graphical output from **anova1**. The sepal width was used for this analysis, and we see a notched box-plot of the three groups. There appears to be significant evidence that the **medians** between group) and the others are different because the notched intervals do not overlap.

The results of the ANOVA test are shown in the table. The second column is the sum of squares (SS); the third column is the degrees of freedom; and the fourth column is the mean of squares (SS/df). The observed value of the F-statistic and the corresponding p-value are also shown. The p-value is very small, so we have evidence that at least one pair of group means is significantly different.

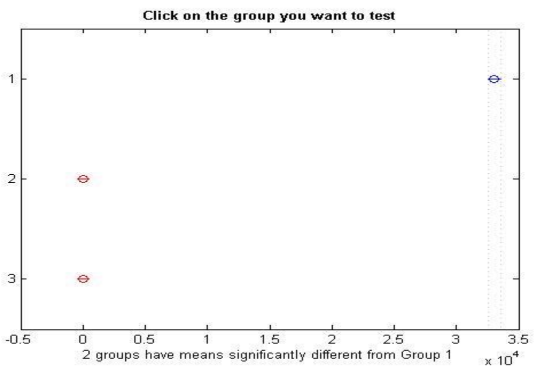

Fig 29. This figure shows the graphical output of the multiple testing. The circle shoes the calculated average and the line consists in the credibility of 95% for the calculated average.

TABLE V - The table generated from the multiple testing simulation in Matlab

1	2	9.3466	9.34643	9.6682
1	3	9.9536	9.2356	9.9685
2	3	-0.9365	0.3465	-0.4677

The interval [9.3466, 9.6682] does not contain zero, and so we can conclude that this couple has a significant margin.

In the table below we have presented the coefficients of determinations generated from the Lagrange fitting.

TABLE VI - The overview of the Dependencies of the Parameters to the Coefficients of Determination

Dependencies	The coefficient of the determination (R^2)
Temperatures– Generator voltage	0.996
Temperatures – Generator current	0.996
Temperatures– Generator active power	0.996
Temperatures – Generator reactive power	0.996
Temperatures – Generator excitation voltage	0.995
Temperatures – Generator excitation current	0.995
Temperatures – Generator's active power of the contactor	0.971
Temperatures – Generator's reactive power of the contactor	0.971

Below we have summarized the table with the ANOVA coefficients:

TABLE VII - The coefficients of ANOVA table

Dependencies	The coefficient of the ANOVA table
Temperatures– Generator voltage	9.6457
Temperatures – Generator current	1.7701
Temperatures– Generator active power	6.9262
Temperatures – Generator reactive power	2.3835
Temperatures – Generator excitation voltage	4.4457
Temperatures – Generator excitation current	1.1312
Temperatures – Generator's active power of the contactor	6.2685
Temperatures – Generator's reactive power of the contactor	5.5569

IV.CONCLUSIONS

In this article we gave the results of the simulation via Matlab [4] of the dependency of the generator's electric parameters of an aggregate in a hydropower plant versus the temperature of winding and oil of a power transformer of this aggregate [8].

According to the theory of transformers we are aware that the greater the energy held by the aggregate, the greater the temperature of the winding and oil of the power transformer is [6]. However, we can say that a precise mathematical relation between temperature of the oil and winding of the power transformer and the electrical parameters of the generator does not exist [11].

Therefore, we have used statistical methods of the data processing which provide a continuity trend of these data and this trend is reflected in a equation of line which may be linear or not, and a coefficient of determination [6]. This coefficient is an indicator that shows the order of dependency of data from each other [9].

The first results of this paper have consisted in presenting the Lagrange interpolation of the generator voltage versus temperature of the winding and oil of the generator. Then, we have performed simulations in Matlab [4] for the Lagrange approximation reflection of other parameters of the aggregate (White et al. 2000). The parameters considered, in this article are, the generator voltage, the generator current, the generator active power, the generator reactive power, the excitation voltage of the generator, the excitation current of the generator, the generator's active power of the contactor and the generator's reactive power of the contactor [10]. It should be emphasized that these parameters have been at the position of the independent variable, which lie in the function of the temperature of the winding and oil of the transformer [14].

Also to verify the hypothesis which consists in the fact that, the greater the energy held by the aggregate, the greater the temperature of the winding and oil of the power transformer we have implemented the ANOVA table coefficients as well the graphical interpretation of these results. Furthermore the multiple testing is simulated to verify this point [19].

The results are such evident because the sampling time was during the summer season and the aggregate did not operate with full force due to lack of rainfall. This means that convey energy from the generator to the transformer has been relatively small and this is reflected in the winding and oil temperature of the power transformer [7].

The limitations of this paper are related to the fact that we have used the Lagrange interpolation to give the tendency of these data which may lead to a prediction of this dependency. This meant that using other interpolation methods and algorithms would lead to more accurate results in such approaches.

V.REFERENCES

[1] Boudreaux-Bartels, G. F. and Murry, R. Time-frequency signal representations for biomedical signals. In: *The Biomedical Engineering Handbook*. J. Bronzino (ed.) CRC Press, Boca Raton, Florida and IEEE Press, Piscataway, N.J., 1995. This article presents an exhaustive, or very nearly so, compilation of Cohen's class of time-frequency distributions.

[2] Bruce, E. N. *Biomedical Signal Processing and Signal Modeling*, John Wiley and Sons, New York, 2001. Rigorous treatment with more of an emphasis on linear systems than signal processing. Introduces nonlinear concepts such as chaos.

[3] Heathcote, M., (1998) "The J & P transformer book", Newnes, pp. 346 – 353

[4] Katsikis, V. (2012) "Matlab – a fundamental tool for scientific computing and engineering applications – volume 1", InTech, pp. 17-31

[5] Katsikis, V. (2012) "Matlab – a fundamental tool for scientific computing and engineering applications – volume 2", InTech, pp.153-170

[6] Lyshevski. S,. (2003) "Engineering and Scientific Computations Using MATLAB" (John Wiley & Sons.), pp. 134-136

[7] Machowski, J., Bialek, J., Bumby, J., (2008) "Power system dynamics: stability and control", Wiley, pp. 103-106

[8] Marques, J.P., (2007) "Applied statistics using SPSS. STATISTICA, MATLAB and R", (Springer), pp. 230-235

[9] Martinez. W,. (2000) "Exploratory Analysis with MATLAB", (Chapman & HALL/CRC), pp. 126-132

[10] Matinez, W., (2002) "Computational statistics handbook with Matlab", (Chapman & HALL/CRC), pp. 343-353

[11] Otto, S., (2005) "An introduction to programming and numerical methods in MATLAB", Springer, pp. 167 - 169

[12] Saadat , H., (1999) "Power system analysis", McGraw-Hill, pp. 126-142

[13] Sivanadam, S., Sumathi, S., Deepa, S., (2007) "Intruction to fuzzy logic using Matlab", Springer, pp. 65-72

[14] Sonka, M., Hlavac V., and Boyle R. Image processing, analysis, and machine vision. Chapman and Hall Computing, London, 1993. A good description of edge-based and other segmentation methods.

[15] Stearns, S.D. and David, R.A *Signal Processing Algorithms in MATLAB*, Prentice Hall, Upper Saddle River, NJ, 1996. Good treatment of the classical Fourier transform and digital filters. Also covers the LMS adaptive filter algorithm. Disk enclosed.

[16] Wang , L. (2009) "Model predicive control system design and implementation using

[17] White, R., (2000) “Computational Mathematics: Models, Methods and analysis with Matlab and MPI”, (CRC Press), pp. 256-267

[18] Winders, J., (2002) “Power transformers: principles and applications”, Marcel Dekker, pp. 68-79

[19] Yang, W., (2005) “Applied numerical methods using Matlab”, (John Wiley & Sons.)pp. 117-120