

Multivariate analysis of important squirrel cage motor parameters

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Abstract. This paper regards the multivariate analysis of data for a three phase asynchronous electrical machine of 300 W equipped with a squirrel cage rotor. The recorded data are the following parameters of the motor: torque (M), rotation speed (n), voltage (U) and current (I). The aforementioned parameters are measured for both, the star and the delta configuration and this data measured is the basis of the multivariate analysis proposed by this paper.

Keywords. multivariate analysis, principal component analysis, factor analysis, torque, rotation speed, voltage, current

1. Measurement of the parameters to be analyzed using multivariate analysis

The motor considered for analysis is a three phase asynchronous motor of 300W, with squirrel-cage rotor. This motor is put into operation first using the star configuration and afterwards using the delta configuration. The motor is then braked down to its nominal speed using the brake mode „torque control”.

Using an ammeter and a voltmeter, the phase variables U_{phase} and I_{phase} are measured at the same time. The measured values are analysed and interpreted using multivariate analysis, this is to say, principal component analysis and factor analysis.

The measured values of torque (M), rotation speed (n), voltage (U) and current (I) for the star configuration are synthesized in the Table1 and the same parameters values measured for the delta configuration are synthesized in the Table2.

Torque – M (Nm)	Rotation speed – n (1/min)	Voltage: Uphase – U (V)	Current: Iphase – I (A)
0.0	3000	225	0.15
0.1	2910	225	0.21
0.3	2830	224	0.31
0.5	2720	224	0.44
0.7	2570	225	0.59
0.9	2270	225	0.87

Table 1. Measured values of M, n, U, I for the star configuration

Torque – M (Nm)	Rotation speed – n (1/min)	Voltage: Uphase – U (V)	Current: Iphase – I (A)
0.0	2975	225	0.49
0.5	2919	225	0.61
1.0	2847	225	0.82
1.5	2752	225	1.15
2.0	2605	225	1.58
2.5	2320	223	2.24

Table 2. Measured values of M, n, U, I for the delta configuration

By visualizing the data in the Table 1 and Table 2 the following conclusions can be made:

- in star configuration the phase current is lower
- a delta configuration offers a better speed/torque ratio as compared to star configuration

The characteristics corresponding to data in Table 1 and Table 2 are represented in the following figures:

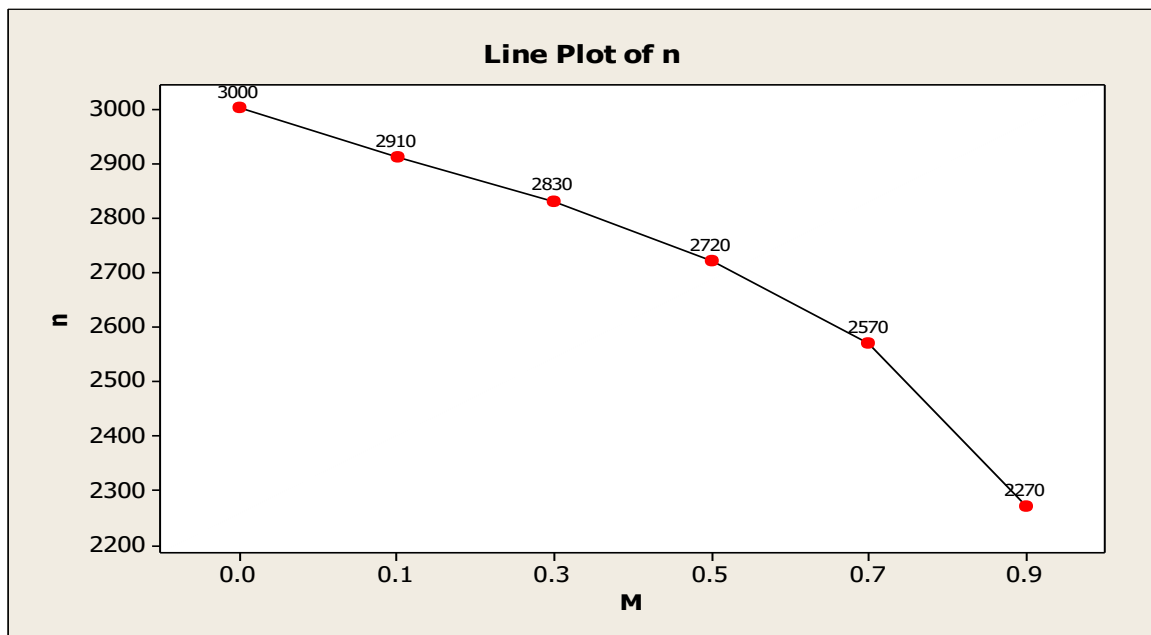


Figure 1. Rotation speed/ Torque characteristic for star configuration

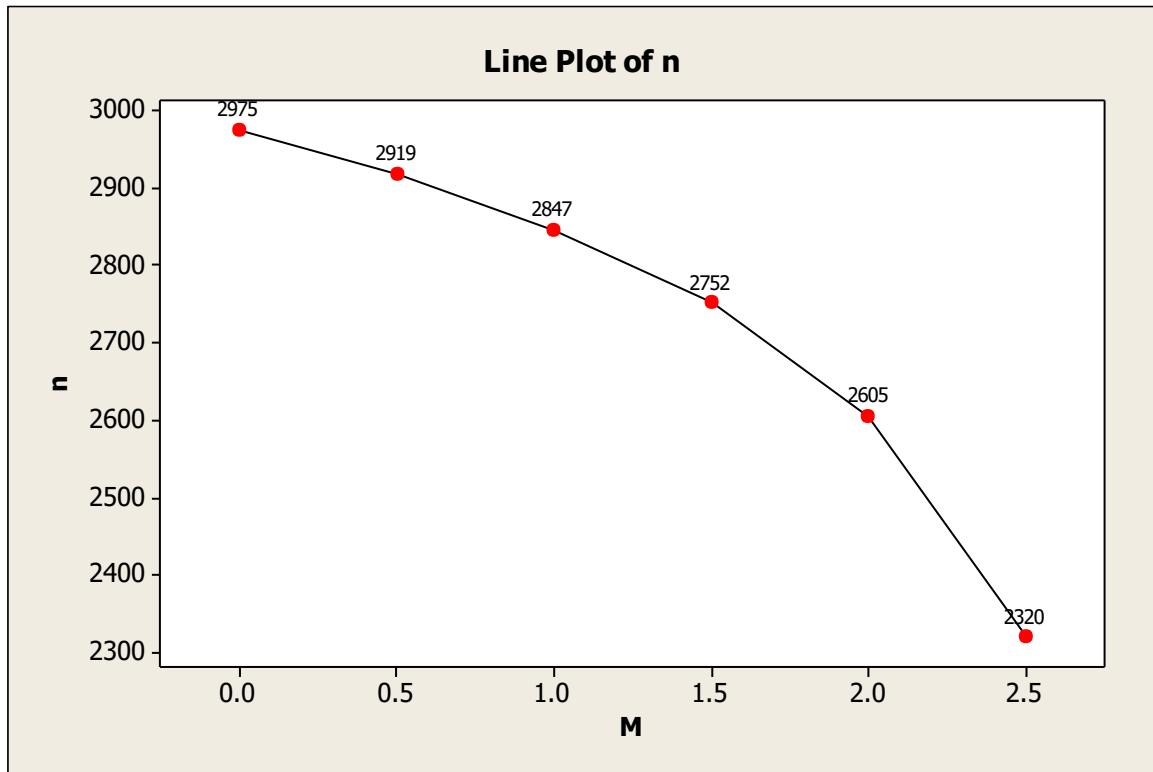


Figure 2. Rotation speed/ Torque characteristic for delta configuration

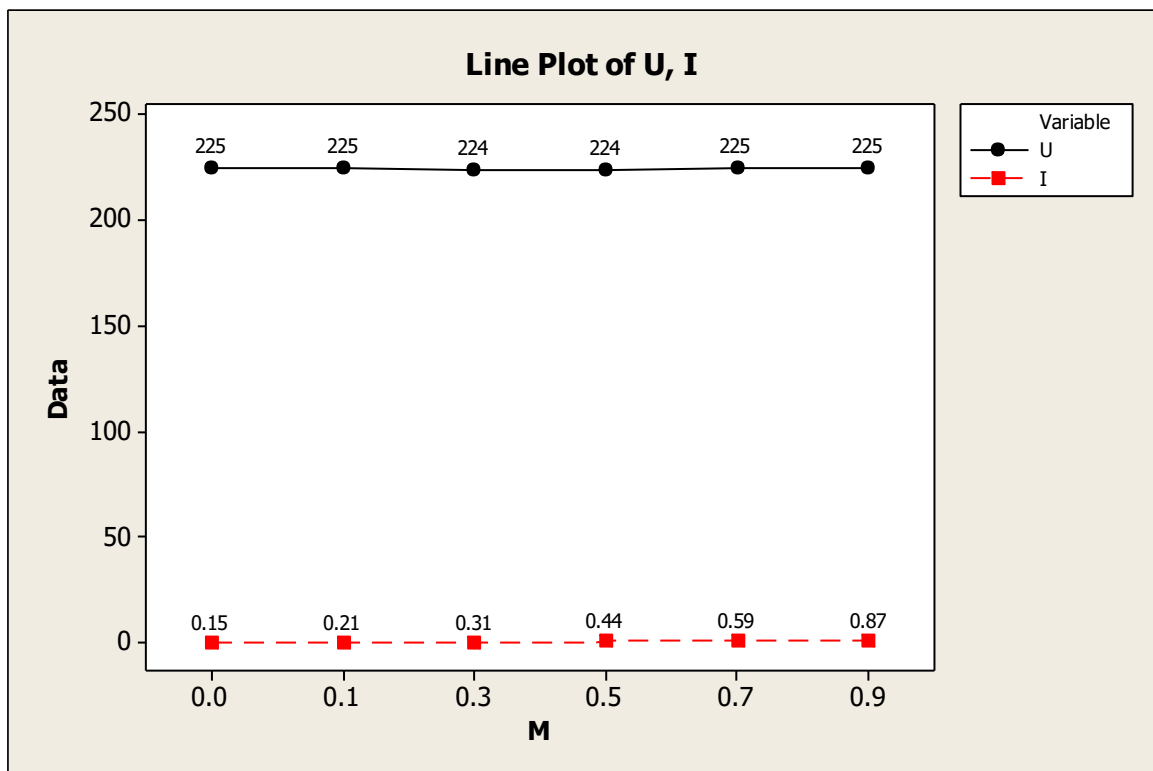


Figure 3. Voltage and current depending on torque for star configuration

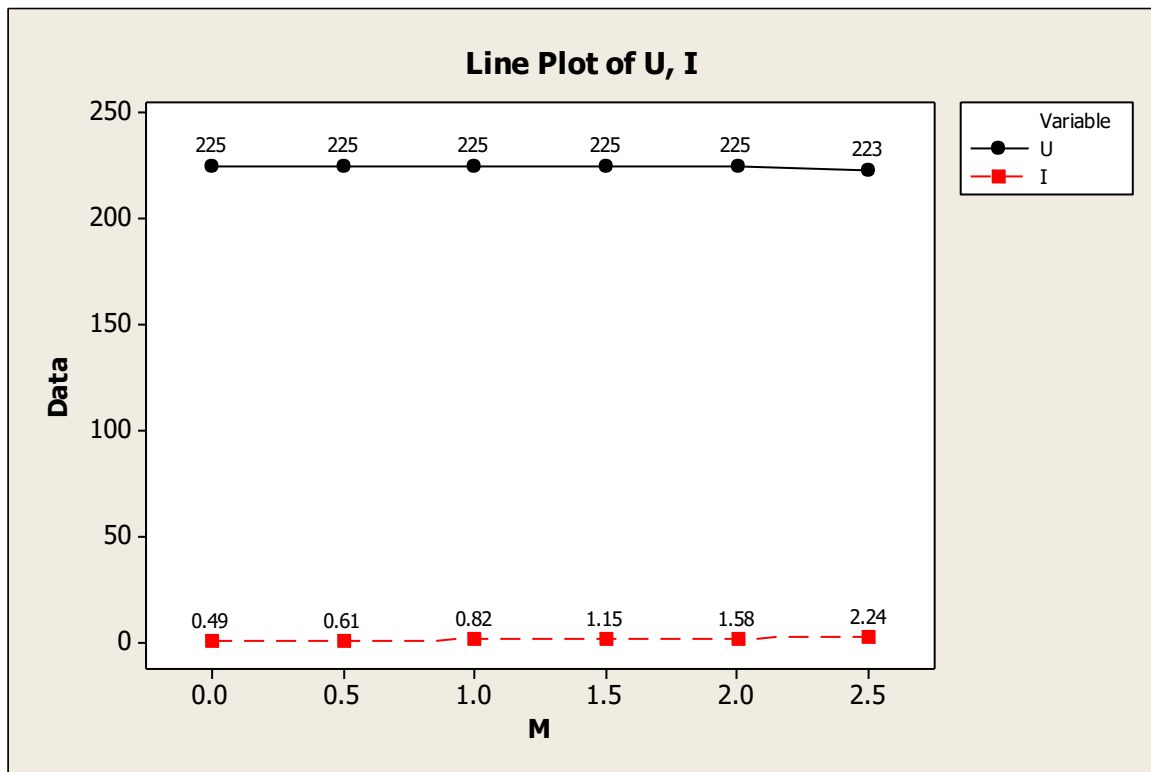


Figure 4. Voltage and current depending on torque for delta configuration

2. Multivariate analysis of parameters data recorded

Multivariate analysis of data means to employ both methods, Principal Component Analysis and Factor Analysis, two different methods, both intended to reduce the number of original variables.

While the principal component analysis gives the directions with the largest variation of the data, factor analysis method reduces the number of original variables to fewer variables, named factors, using the correlations between the original variables.

Both methods are using the singular value decomposition of the correlation matrix associated with the original variables.

2.1 Multivariate analysis for star configuration data

2.1.1 Principal Component Analysis: M, n, U, I for star configuration

Eigenanalysis of the Correlation Matrix

Eigenvalue	2.9896	0.9888	0.0208	0.0008
Proportion	0.747	0.247	0.005	0.000
Cumulative	0.747	0.995	1.000	1.000

Variable	PC1	PC2
M	0.568	-0.146
n	-0.577	0.009
U	0.105	0.989
I	0.578	-0.027

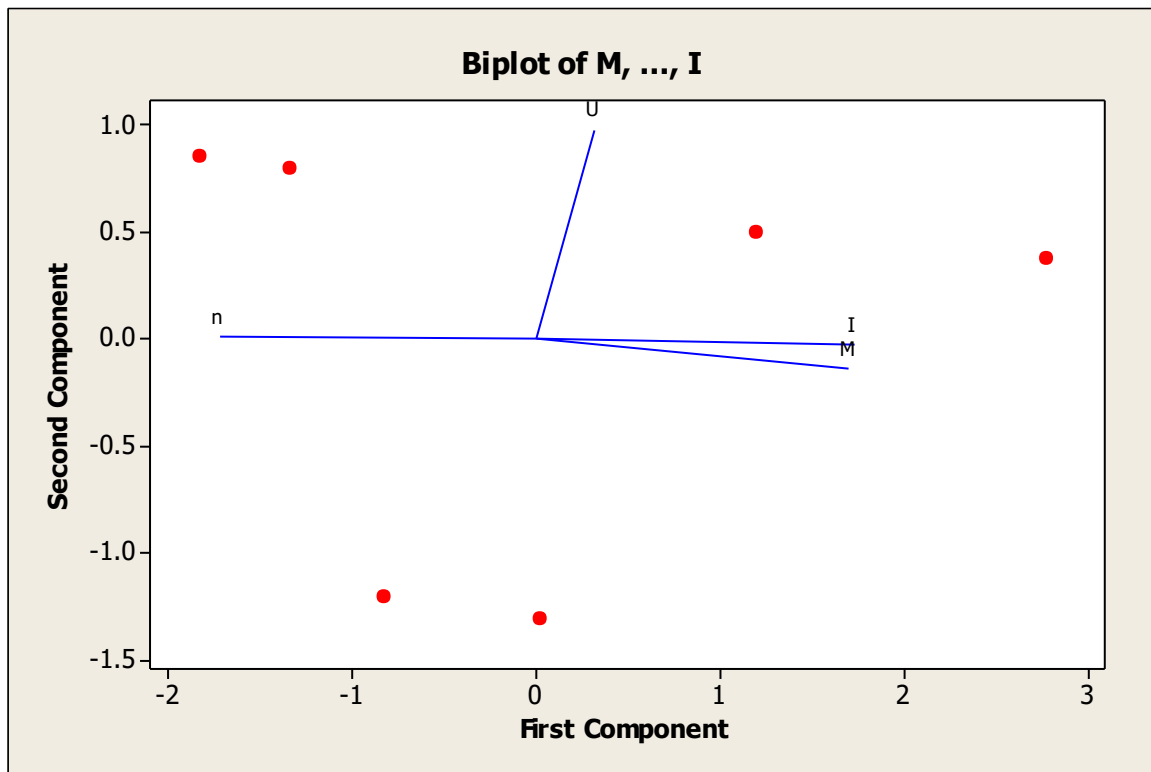


Figure 5. Biplot for principal component analysis - star configuration

2.1.2 Factor Analysis: *M, n, U, I* for star configuration

Principal Component Factor Analysis of the Correlation Matrix

Unrotated Factor Loadings and Communalities

Variable	Factor1	Factor2	Communality
M	0.983	-0.145	0.987
n	-0.997	0.009	0.994
U	0.181	0.983	1.000
I	0.999	-0.027	0.998

Variance	2.9896	0.9888	3.9784
% Var	0.747	0.247	0.995

Factor Score Coefficients

Variable	Factor1	Factor2
M	0.329	-0.147
n	-0.333	0.009
U	0.061	0.994
I	0.334	-0.027

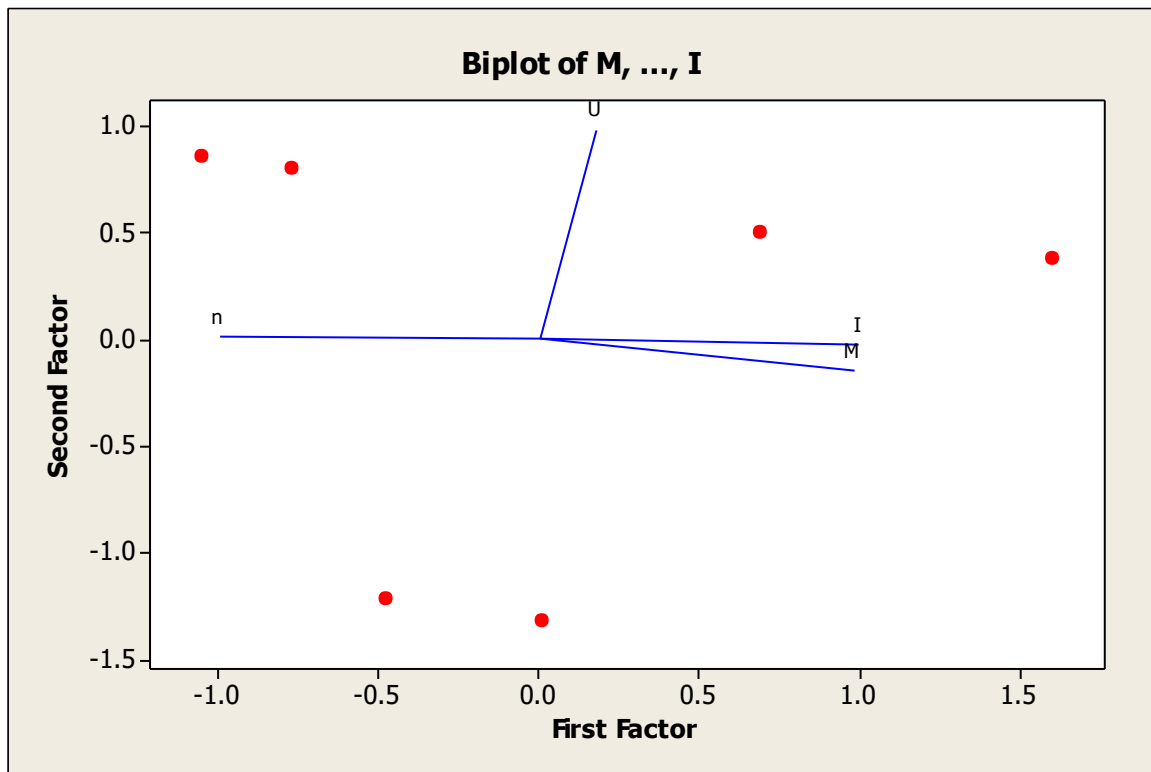


Figure 6. Biplot for factor analysis - star configuration

2.2 Multivariate analysis for delta configuration data:

2.2.1 Principal Component Analysis: M, n, U, I for delta configuration

Eigenanalysis of the Correlation Matrix

Eigenvalue	3.6184	0.3690	0.0123	0.0003
Proportion	0.905	0.092	0.003	0.000
Cumulative	0.905	0.997	1.000	1.000

Variable	PC1	PC2
M	-0.496	-0.528
n	0.525	0.058
U	0.453	-0.832
I	-0.522	-0.162

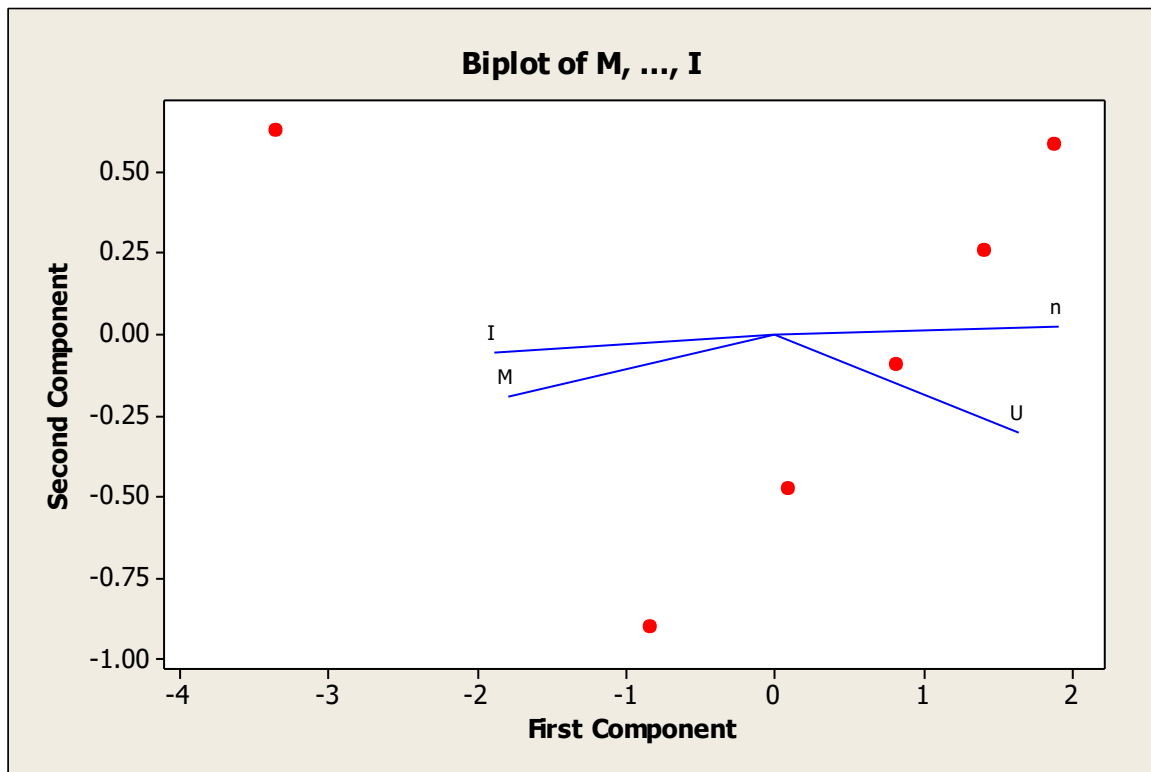


Figure 7. Biplot for principal component analysis - delta configuration

2.2.2 Factor Analysis: M, n, U, I for delta configuration

Principal Component Factor Analysis of the Correlation Matrix

Unrotated Factor Loadings and Communalities

Variable	Factor1	Factor2	Commuality
M	-0.944	-0.321	0.994
n	0.999	0.036	0.999
U	0.862	-0.505	0.999
I	-0.993	-0.098	0.996

Variance	3.6184	0.3690	3.9874
% Var	0.905	0.092	0.997

Factor Score Coefficients

Variable	Factor1	Factor2
M	-0.261	-0.869
n	0.276	0.096
U	0.238	-1.369
I	-0.274	-0.266

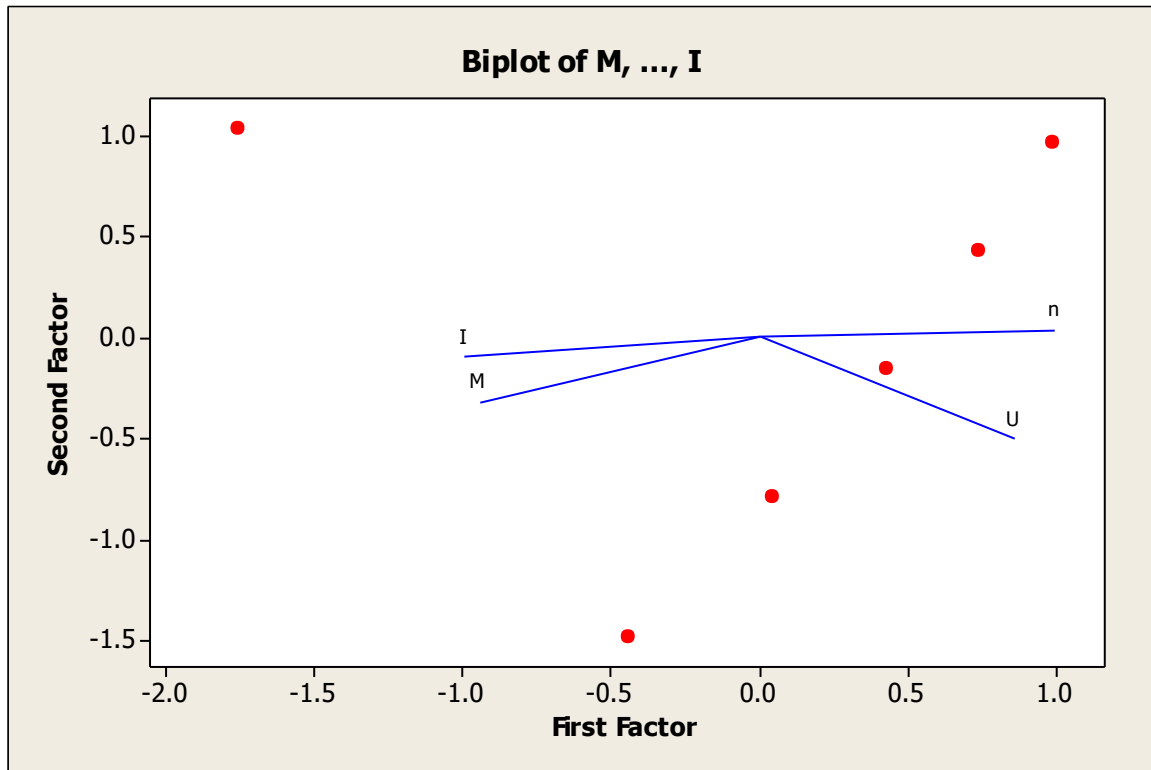


Figure 8. Biplot for factor analysis - delta configuration

3. Results and interpretation

Performing Principal Component Analysis and Factor Analysis on the available recorded data, the results obtained can be interpreted as follows:

For the star configuration, the first two components, respectively the first two factors explain 99,5% of the total variation, where the first component/factor explains 74,7% of the total variation and the second component/factor explains 24,7% of the total variation

For the delta configuration, the first two components, respectively the first two factors explain 99,7% of the total variation, where the first component/factor explains 90,5% of the total variation and the second component/factor explains 9,2% of the total variation.

The corresponding scree plots for the star configuration and for delta configuration are presented in the Figures 9 and 10 below.

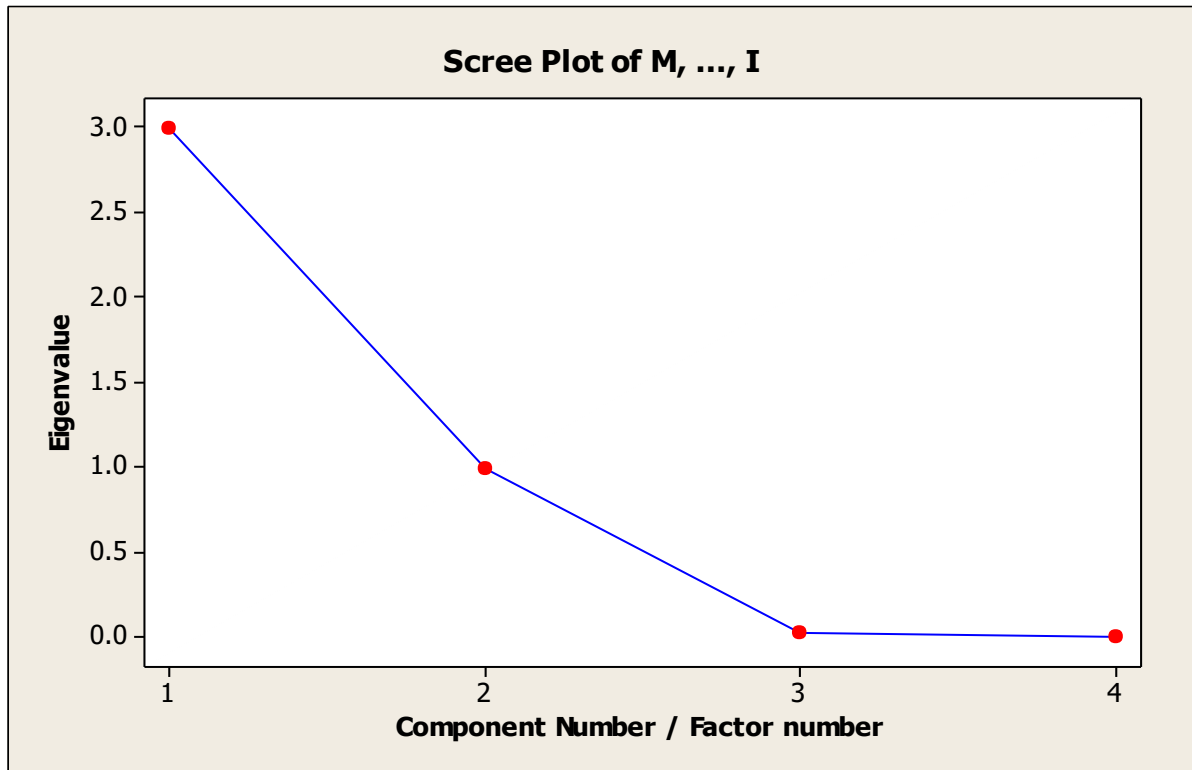


Figure 9. Scree plot for component/factor analysis - star configuration

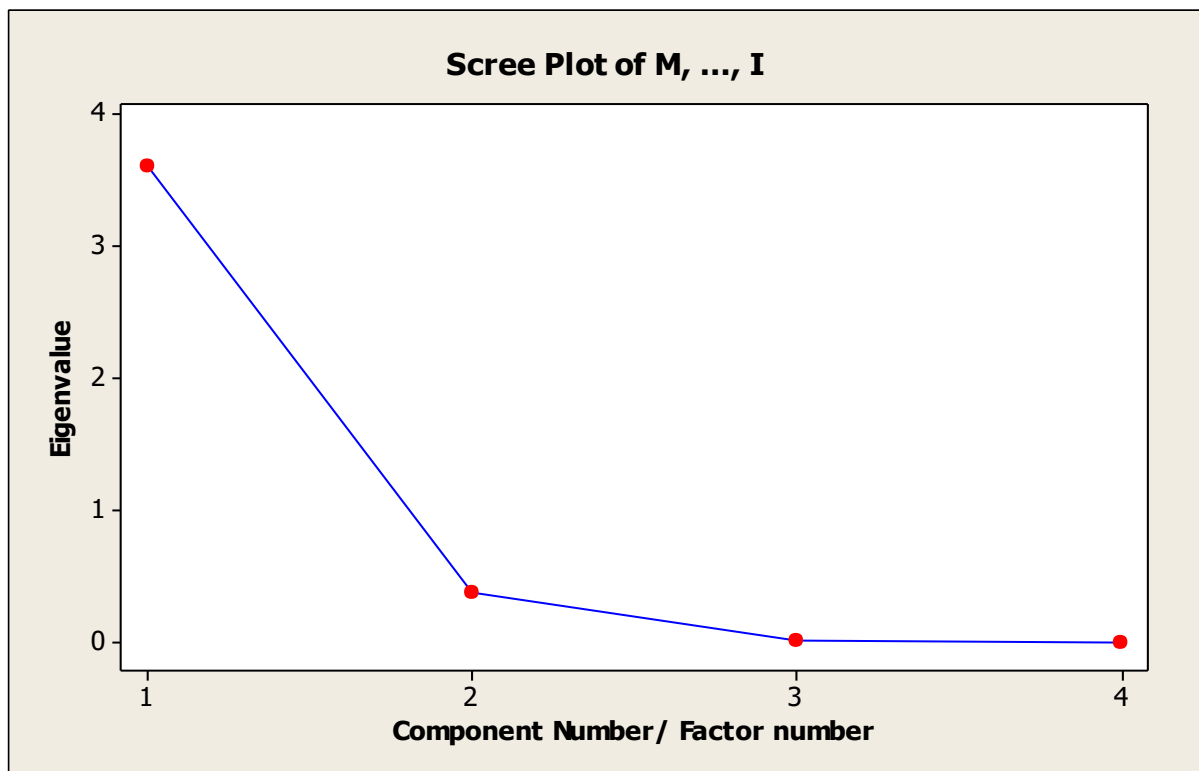


Figure 10. Scree plot for component/factor analysis - delta configuration

Taking into account that the higher the component/factor loading the more important the variable to the component is, it can be concluded that for the star configuration the variables M, n and I have approximately the same significance to the first component/factor, while the variable U has a much lower significance for that component/factor.

For the delta configuration the variables M, n, U, I have approximately the same significance to the first component/factor, while to the second component/factor the variables U and M have a much higher significance than the other two variables n and I.

The component/factor scores are calculated for each of the six recordings (for both – star and delta configuration) using the Z-transformed matrix of the data in each case and the values of the principal components/factor score coefficients.

Looking at the biplots for star configuration and delta configuration the component/factor scores obtained (represented by the points in the biplots) for each of the six data recordings can be observed. The signification of these scores is that a high score on a single component/factor means that the recorded values are mainly explained by this single component.

4. Conclusions

The number of the four analysed parameters recorded: torque (M), rotation speed (n), phase voltage (U) and phase current (I) can be reduced using the proposed multivariate methods: principal component analysis and factor analysis.

The components/factors explaining 99,5% (star configuration), respectively 99,7% (delta configuration) of the total amount of the variation of data are the first two components/factors, so the number of variables can be reduced to only two latent factors which are able to explain a significant amount of the variation in the recorded data.

Although very useful for explaining the relationships between the data and for simplification reasons, this reduction of the number of the variables produces a certain loss of information. In addition to this, the components obtained by applying the multivariate analysis are orthogonal.

References

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