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# Statistical process control applied in the analysis of defects in asynchronous electrical machines

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**Abstract**. This paper refers to defects recorded for asynchronous electrical motors. The aim of this paper is to conclude about the quality of the production process of the asynchronous electrical machines using the statistical process control. The main objective of statistical process control is to find and conclude about the abnormalities in the production processes, using statistical tools of analysis and control, the so called quality control charts. For a certain measured quality characteristic, analyzing the corresponding control chart of that characteristic, one can conclude about the fact whether the respective process is getting out of the control or it is under control. These conclusions are made using the so called control limits, LCL and UCL (lower and upper control limit).

**Keywords**. statistical process control, three-sigma analysis, control charts, asynchronous electrical machine

## 1. Defect data recorded by a Romanian fabricant of electrical machines and used for the analysis

This paper is using the data referring to defects in electrical machines, namely defects in asynchronous electrical motors of 0,37 kW nominal power, recorded by a main Romanian fabricant of electrical machines and presented in the Table 1 below.

| **Type of defect** | **Luna 1** | **Luna 2** | **Luna 3** | **Luna 4** | **Luna 5** | **Luna 6** | **Luna 7** | **Luna 8** | **Luna 9** | **Luna 10** | **Luna 11** | **Luna 12** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric punctures | 235 | 223 | 313 | 225 | 262 | 319 | 309 | 236 | 321 | 297 | 356 | 226 |
| Phase interruption | 71 | 74 | 64 | 84 | 49 | 92 | 74 | 70 | 133 | 135 | 114 | 111 |
| Asymmetric currents | 62 | 75 | 75 | 39 | 88 | 125 | 137 | 60 | 127 | 165 | 96 | 110 |
| Eccentricity | 286 | 300 | 376 | 344 | 371 | 377 | 373 | 278 | 378 | 377 | 465 | 331 |
| Bearing noise | 79 | 103 | 92 | 59 | 76 | 87 | 114 | 70 | 126 | 97 | 96 | 23 |
| Electromagnetic noise | 37 | 44 | 20 | 12 | 6 | 46 | 43 | 39 | 43 | 31 | 27 | 26 |
| Other defects | 0 | 23 | 22 | 37 | 20 | 19 | 30 | 20 | 0 | 71 | 58 | 28 |
| **Total number of defects** | **770** | **842** | **962** | **800** | **872** | **1065** | **1080** | **773** | **1128** | **1173** | **1212** | **855** |
| **Total number of tested motors** | **15064** | **18616** | **22957** | **20562** | **23942** | **25141** | **24360** | **18277** | **25556** | **23054** | **24511** | **18118** |

**Table 1**. Monthly defects as per type of defect recorded for asynchronous electrical motors

## 2. Statistical process control applied for the defect data recorded

Based on this data and using the statistical process control theory the corresponding p-control chart is represented.

The statistical process control is based on the three sigma ($3\sigma$) theory, a statistical tool used for analysis, control and improvement of production processes.

*2.1 Statistical key indicators calculated based on data recorded:*

The theory used with regard to the presented data, based on the binomial distribution, is the theory of p-charts (where p-chart stands for percent-defective chart). In order to represent the p-charts related to the data from Table 1, and then to conclude about the presented results, one has to calculate the mean proportion defective (p), the standard error of the proportion ($S_p$) and the upper and lower control limits of the charts (UCL and LCL).

The formulas used in order to do these calculations are:

$$p = \frac{Total\ no.defective\ motors}{Total\ no.tested\ motors} \quad (1)$$

$$S_p = \sqrt{\frac{p(1-p)}{n}} \quad (2)$$

$$UCL, LCL = p \pm 3\sqrt{\frac{p(1-p)}{n}} \quad (3)$$

where n stands for sample size of the tested motors. Using the formulas above, it follows the calculated values of the proportion p, $S_p$, UCL and LCL.

Taking into account that the sample sizes are different (total numbers of motors monthly tested) it follows that the $S_p$-values and consequently the values of UCL and LCL are depending on the sample sizes, for each month of recorded defects and recorded tested motors.

The calculated value of mean proportion of defective motors is according to formula (1):

p = 11532/260158 = 0,044327. The following Table 2 comprises the rest of the calculated statistical number values.

| Statistical number | Luna 1 | Luna 2 | Luna 3 | Luna 4 | Luna 5 | Luna 6 | Luna 7 | Luna 8 | Luna 9 | Luna 10 | Luna 11 | Luna 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Defective motors percent** | 0.051115 | 0.04523 | 0.041904 | 0.038907 | 0.036421 | 0.042361 | 0.044335 | 0.042294 | 0.044138 | 0.050881 | 0.049447 | 0.047191 |
| **$S_p$ (Standard error of proportion)** | 0.001677 | 0.001509 | 0.001358 | 0.001435 | 0.00133 | 0.001298 | 0.001319 | 0.001522 | 0.001287 | 0.001356 | 0.001315 | 0.001529 |
| **LCL (lower control limit)** | 0.039296 | 0.039801 | 0.040252 | 0.040021 | 0.040336 | 0.040433 | 0.040371 | 0.03976 | 0.040465 | 0.04026 | 0.040383 | 0.03974 |
| **UCL (Upper control limit)** | 0.049358 | 0.048853 | 0.048402 | 0.048633 | 0.048318 | 0.048221 | 0.048283 | 0.048894 | 0.048189 | 0.048394 | 0.048271 | 0.048914 |

**Table 2**. Statistical numbers calculated for the total monthly defective motors

*2.2 Representation of p-Charts corresponding to the defects data recorded:*

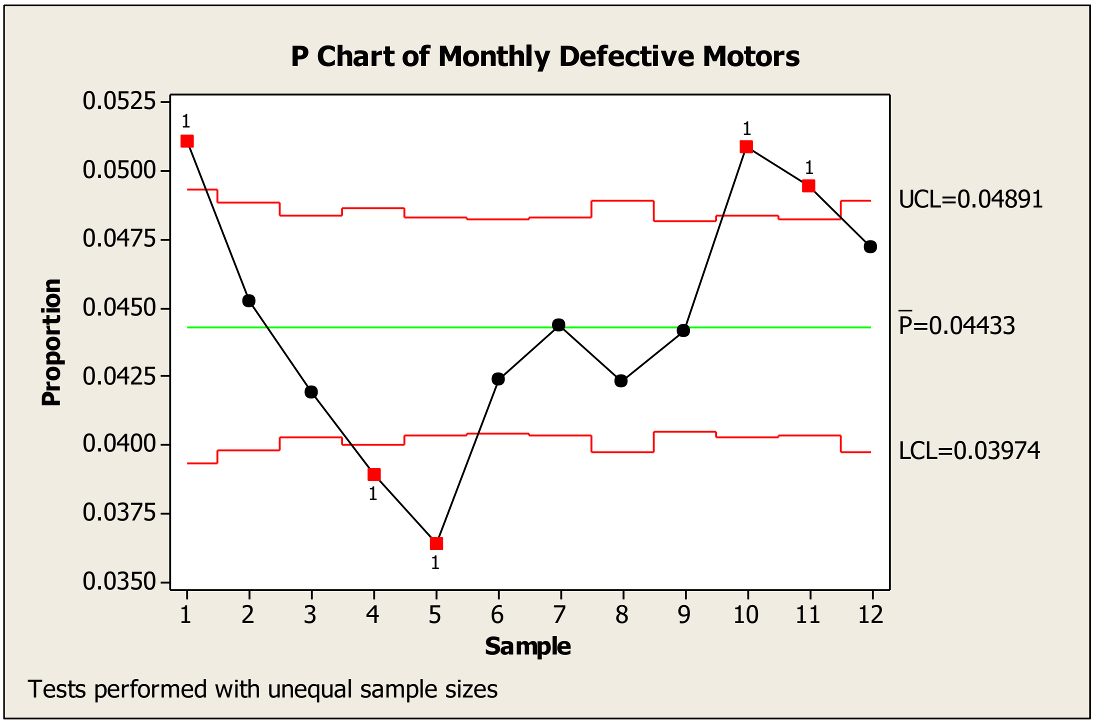


**Figure 1.** p-Chart for Monthly Defective Motors

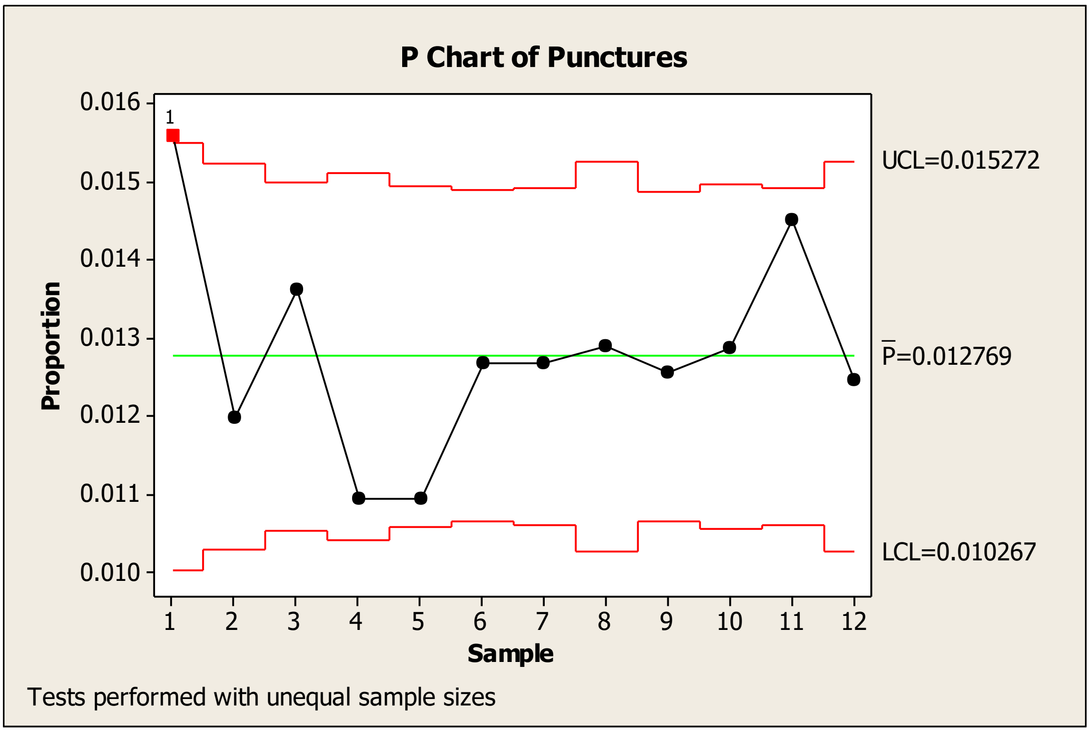


**Figure 2.** p-Chart for Monthly Electric punctures

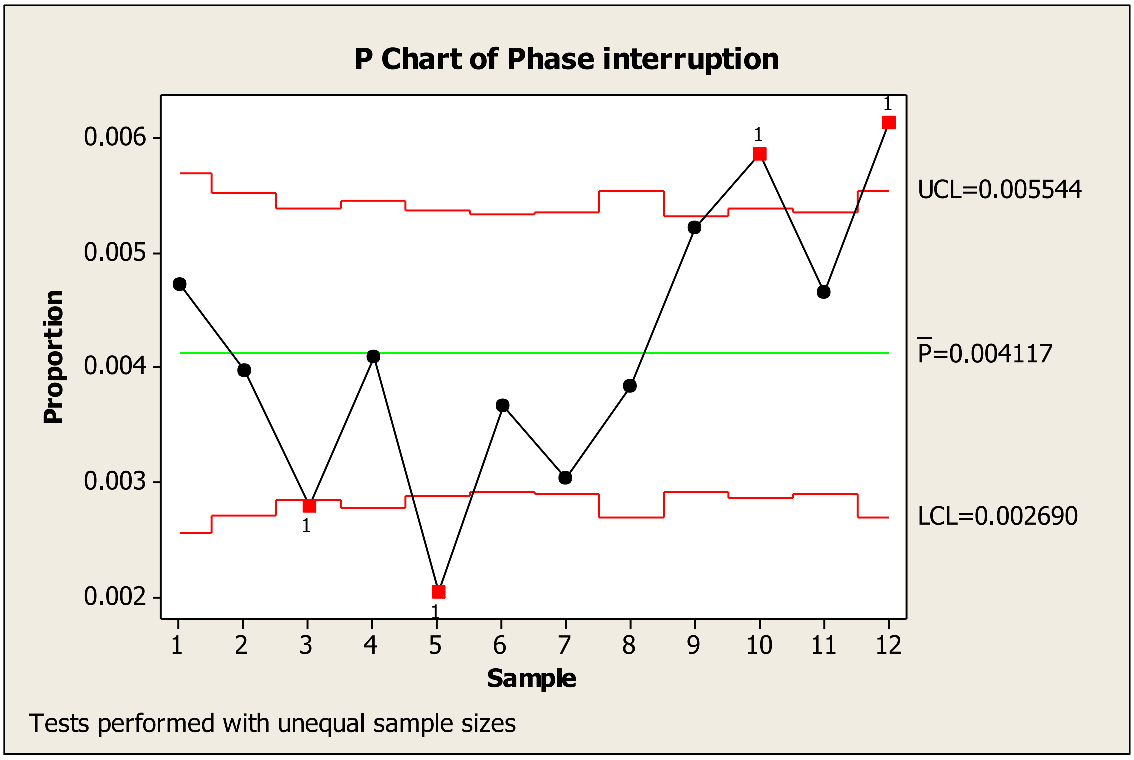


**Figure 3**. p-Chart for Phase interruption defects

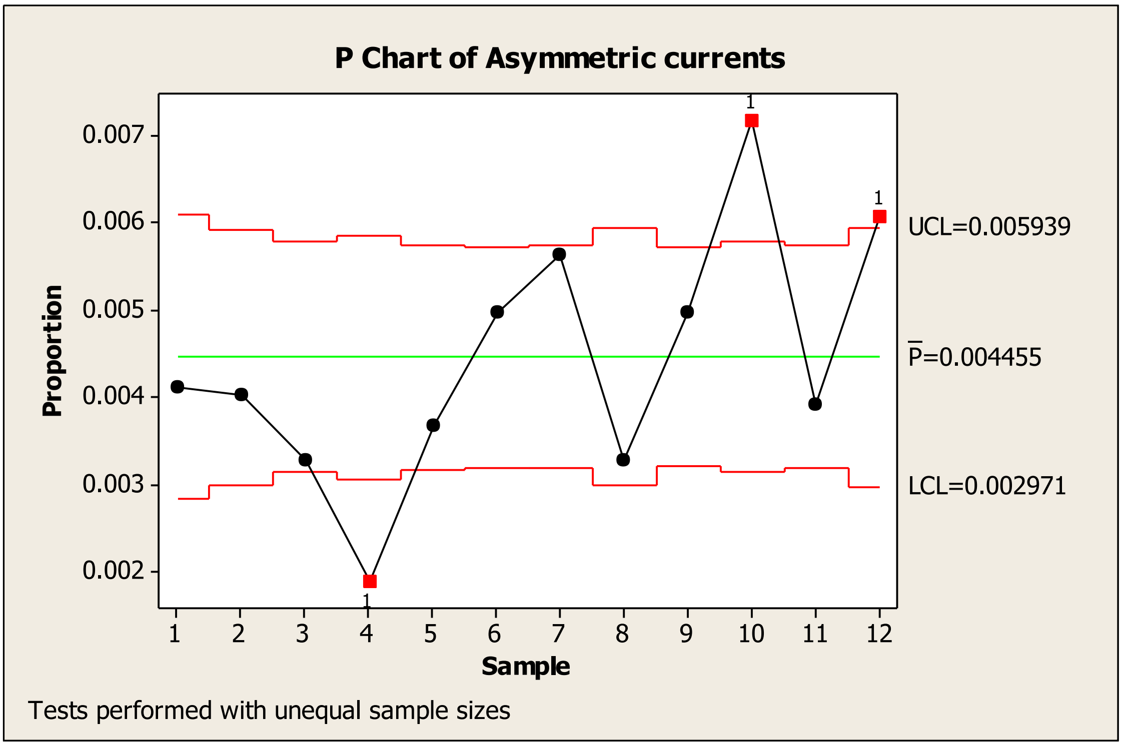


**Figure 4**. p-Chart for Asymmetric currents

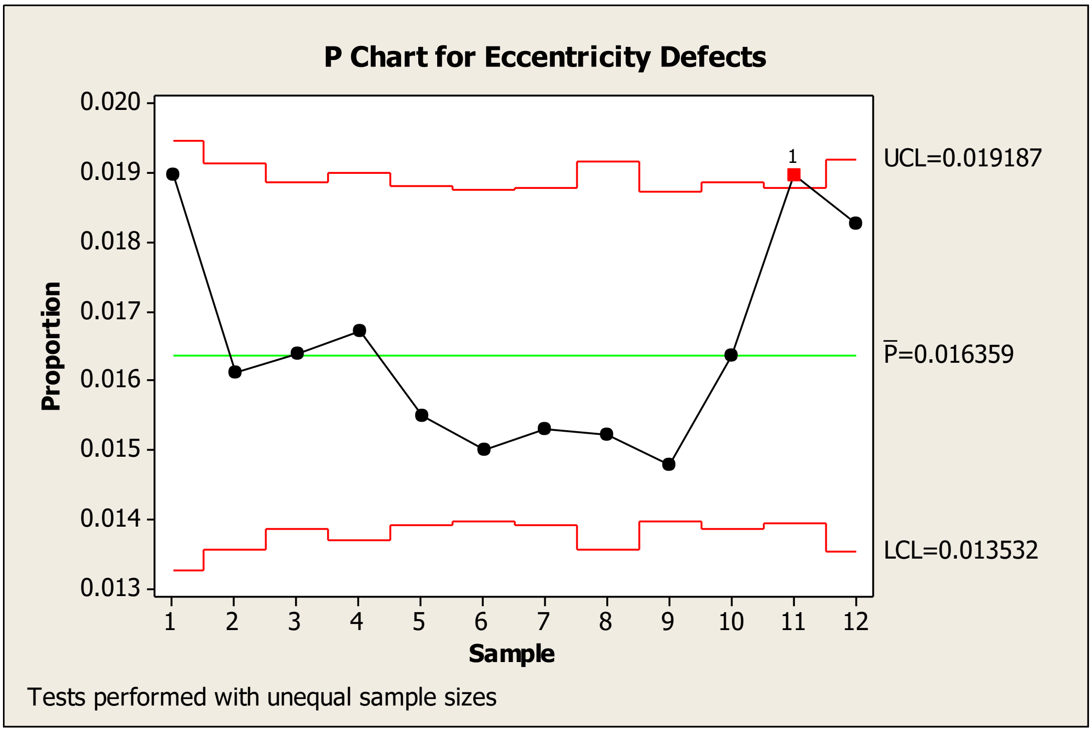


**Figure 5**. p-Chart for Eccentricity defects

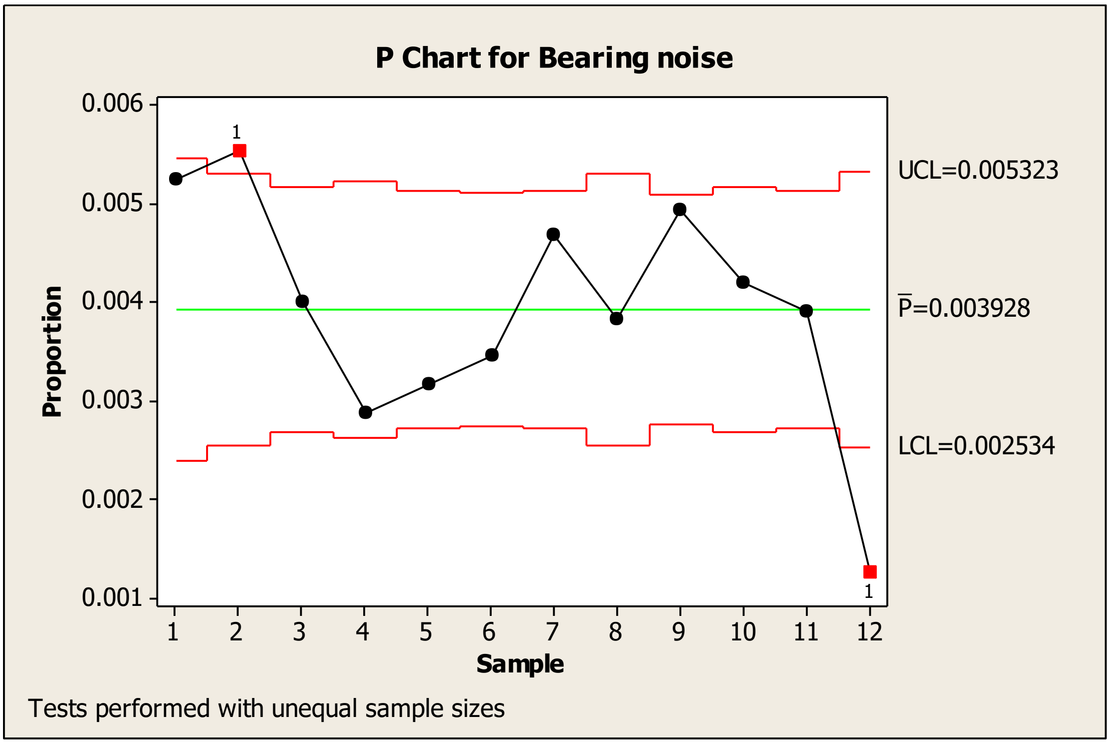


**Figure 6**. p-Chart for Bearing noise

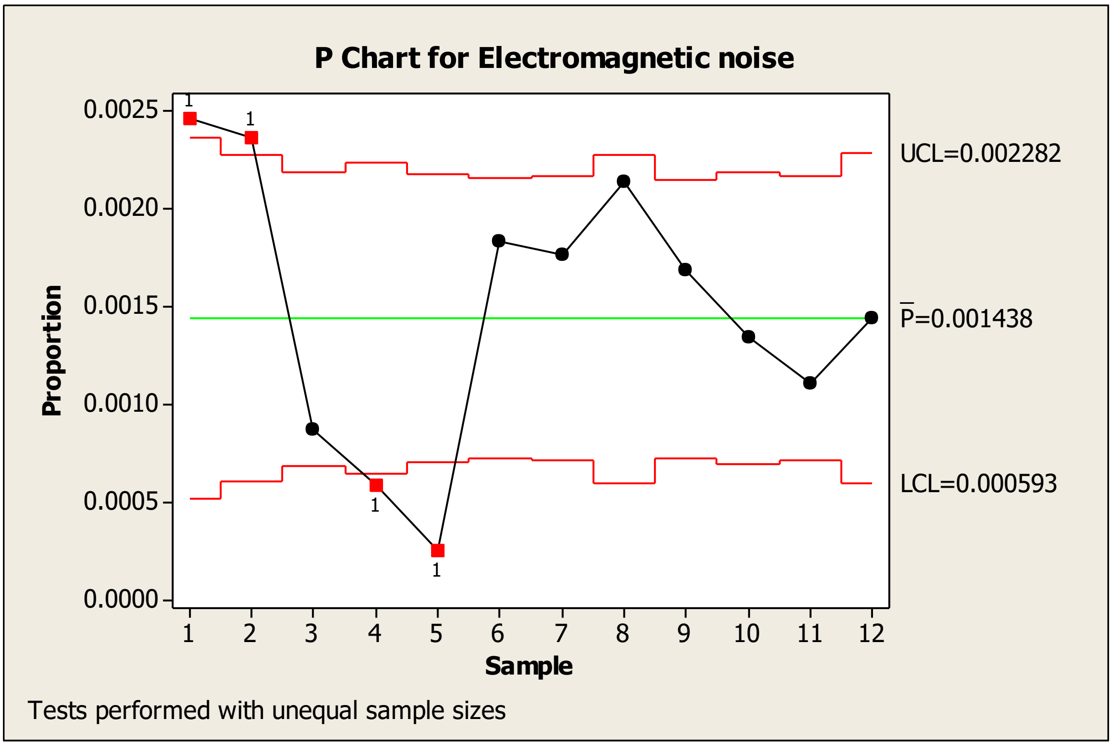


**Figure 7**. p-Chart for Electromagnetic noise

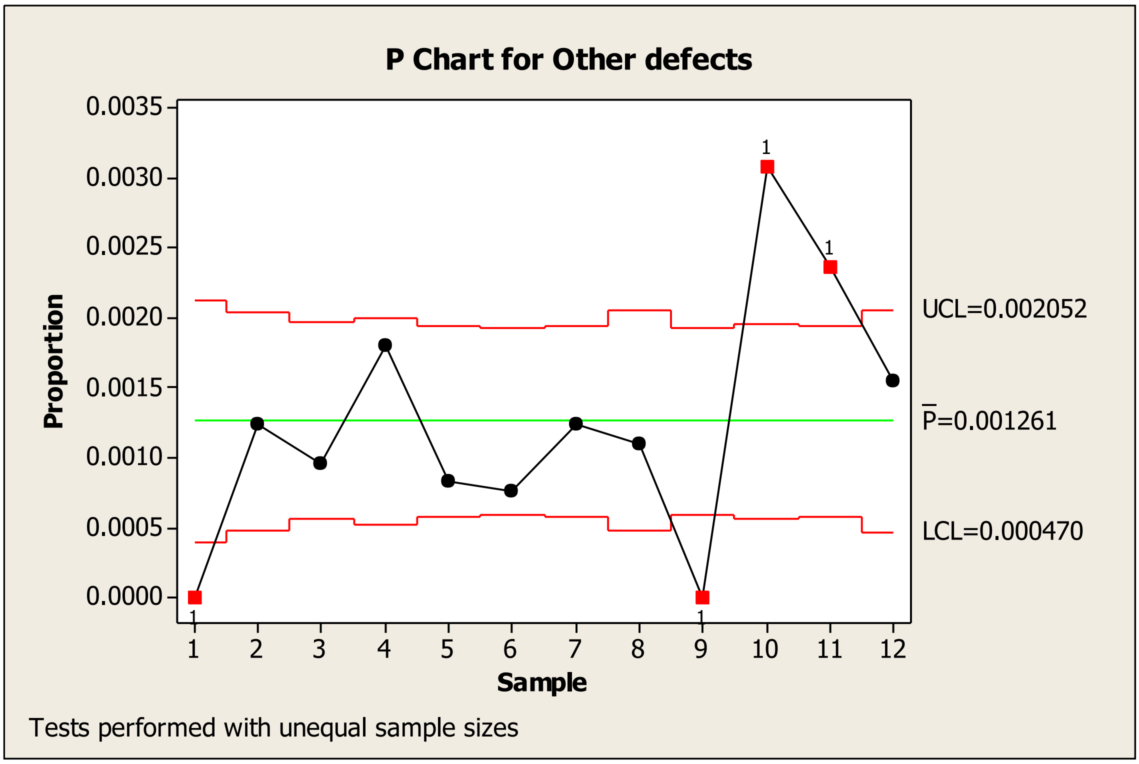


**Figure 8**. p-Chart for Other defects

## 3. Results and interpretation

The p charts above present the results recorded in each line of the Table1, corresponding to each type of recorded defect: electric puncture, phase interruption, asymmetric currents, eccentricity, bearing noise, electromagnetic noise and other defects. The Table2 summarizes the values of statistic numbers calculated for the aggregate number of defects.

As it can be seen from the charts, each of the presented p-charts shows two distinct regions:

- an area situated between the lower control line and upper control line, regarded as the region of acceptability of the process, where the process is said to be "in control"
- a second area situated outside the above acceptability region of the process, where the process is said to be "out of control".

Knowing the evolution of the process summarized by these charts, one can analyse and improve the "out of control" situations occurred in the past, or in other words, one can "control" the process, that is where the general name of the methods proposed in the 1920's by the American Walter Andrew Shewhart comes from, namely statistical process control.

## 4. Conclusions

The Statistical Process Control theory applied in the present paper presents and represents only one of the possible applications of this theory, the most appropriated approach of the available production data recorded during an year by a Romanian fabricant of electrical machines. With regard to the available data are many aspects to be discussed:

The calculations from the paper and consequently the charts presented are using as p-line, the calculated value of the percent defective, out of the data available for the electrical motors (as presented in Table1).

The application of the SPC could be also made for another value of p. This another value of p, determining another p-line and consequently another "in-control region" in our charts, which would be more adequate to use, would be the targeted value of proportion of defective motors.

This p-value could be known for the electrical machines industry of the respective country and of course substantially depends on the performance of the respective country's industry.

This idea leads us to another important idea regarding the issue of Quality, that is the "history of recorded data". Unfortunately, for the recent history of the Romanian industry, where in the central planned economy more important was the quantity and little attention was paid to the quality in the past seven decades, there were very few data in respect of the quality recorded.

This approach gives us an additional explanation of the poor performance of Romanian industry which unfortunately is lacking besides important knowledge also important quality data, as compared to the western industries.

With direct reference in this respect, the application of Statistical Process Control and other useful quality assurance methods requires additionally to knowledge, also the data recorded through years of observations.

Only based on historical data, much of the statistical numbers have sense and can be determined in direct connection with the sample sizes and used successfully. This applies especially for this presented area of statistical quality and process control, where, for example the coefficients for the lower and upper control lines for mean and range charts, are only known in direct connection with the respective industry and strongly depend on the analysed sample sizes.

Although initially by Walter A. Shewhart discovered, the application and utility of these methods were thoroughly and fully understood, first of all, by the Japanese who borrowed the methods during their industry reconstruction after the second world war. They successfully applied and substantially improved the methods of quality control and completed them with new concepts through their representants such as Kaouru Ishikawa or Genichi Taguchi.

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