PREDICTING THE FAILURES OF TRANSFORMERS IN A POWER SYSTEM USING THE POISSON DISTRIBUTION: A CASE STUDY

Abdurrahman ÜNSAL Bekir MUMYAKMAZ N. Serdar TUNABOYLU

e-mail: unsal@dumlupinar.edu.tr mumyakmaz@dumlupinar.edu.tr serdar.tunaboylu@dumlupinar.edu.tr
Dumlupinar University ,College of Engineering, Department of Electrical & Electronics Engineering, Tavsanlı Yolu 10. KM 43100, Kütahya, Turkey

Key words: Poisson distribution, failure rate, power system reliability, maintenance

ABSTRACT

In this study, the Poisson distribution is used in predicting the failures of components in power systems. In order to evaluate the validation of the study the statistical maintenance/repair data from the state utility company of Adiyaman district was used. The results show that the Poisson distribution can be used to schedule the preventive maintenance and improvement of power system reliability purposes.

I. INTRODUCTION

Poisson distribution, which was developed by Simon Denis in 1837 is one of the three discrete distributions (Binomial, Hypergeometric, and Poisson) that uses integers as random variables [1]. The Poisson equation for predicting the probability of a specific number of defects or failure (r) in time (t) is given as follows:

$$P(r) = \frac{(\lambda t)^r e^{-\lambda t}}{r!} \qquad (1)$$

where:

r = number of failures in time (t)
λ = failure rate per hour
t = time expressed in hours
P(r) = probability of getting exactly r failures in time t

In order to determine the probability of k or fewer failures occurring during time interval t_i, the probability of each failures occurring during the same time interval must be calculated. The probability of each failure occurring can be given as follow:

$$P(r \le k) = \sum_{0}^{k} P(r) \qquad (2)$$

The confidence level (CL) that population has a failure rate (λ) based on r ≤ k failures occurring during time interval (t) is:

$$CL = 1 - P(r \le k) \qquad (3)$$

Due to the discrete nature of the Poisson distribution, it can be applied to power systems to evaluate the reliability of the system regarding failures related to the components of the power system. It can also be used for scheduling of the preventive maintenance, recruiting of the repair crew and planning/purchasing purposes of the spare components and to evaluate the readiness of the system during worst case problems/failures (Since the failure of each component in a power system is discrete).

There are various components such as transformers, relays, fuses, circuit breakers, power lines, poles, etc in a power system. The failure of some components may affect the failure of other components. Therefore, the failure of each of these components may not be independent of the others. The analysis shown here are the preliminary results of a comprehensive study related to the evaluation of power system reliability. Therefore it is assumed that the failure of each component is independent of the others.

II. ANALYSIS

The data provided by the State Utility Company of Adiyaman District is related to the failures of fuses and transformers. The failure of each fuse and/or transformer is assumed to be independent of the other.

There are 1394 transformers installed in combined medium-voltage and low-voltage levels of the power system of the city of Adiyaman. On the average, there are 34 transformer failures per annum.

It is assumed that each transformer failure is repaired immediately. This is a fairly valid assumption since the repair or replacement time is much shorter than the time to failure. Therefore, instant repair for the transformers is assumed. The data provided is recorded in the year 2001.

There were 37 transformer failures and the mean repair time was 22.05 hours in 2001. The failure rate of the transformers is 37 transformers per 8760 hours. The calculations and analysis are carried out first for a time period of 1 year then for a time period of 5 years.

III. RESULTS

The probability density function for the transformers is calculated (using equation 1). By employing a failure rate of 37 transformers per 8760 hours (one year) in the Poisson equation, the probability density function is given in Figure 1. This calculation is carried out for one year. The vertical axis shows the probability of failures while the horizontal axis shows exact n-number of failures. It is obvious from the figure that the probability of getting exactly 34 failures in one year is the highest which indicates that most probably there would be, on the average, 34 failures in a year.

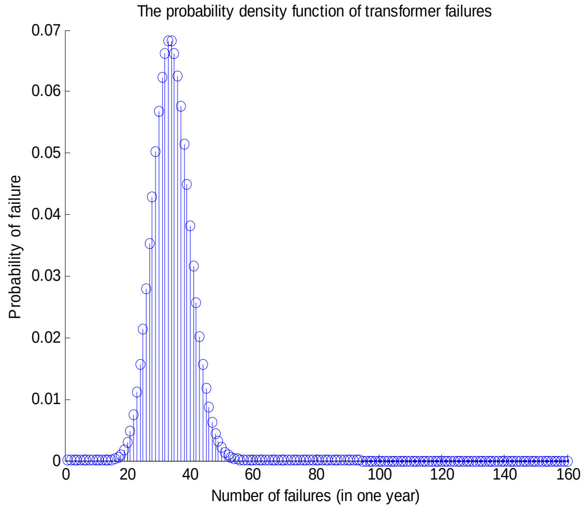

Figure 1. The probability density function of transformer failures

The probability distribution function for a period of one year was also calculated using the equation 2. The results of the probability distribution function are presented in figure 2. The x-axis indicates the probability of occurrence of n-failures or less while the y-axis shows the probability. As expected, the figure shows that the probability of getting 34 transformers or less is about 1 which is in agreement with the data.

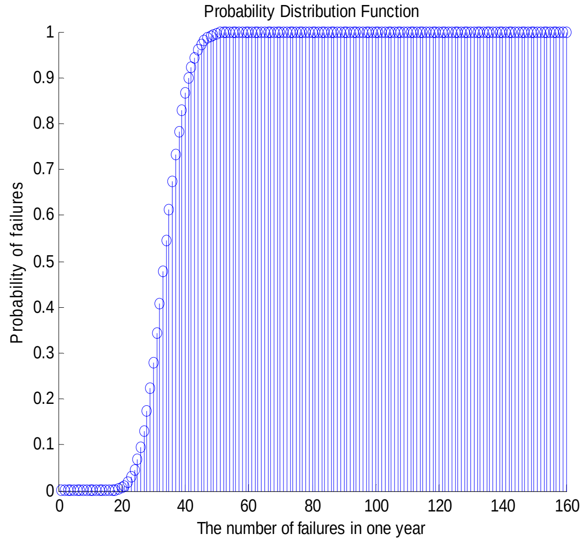

Figure 2. The probability distribution function of the transformer failures

Then the confidence level of transformer failures for a period of one year was calculated using equation 3. The results are given in Figure 3.

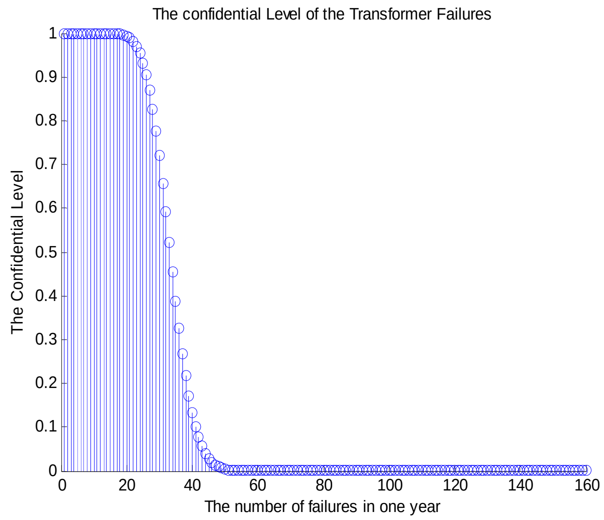

Figure 3. The confidence level of transformer failures

The figure shows the confidence level of getting, for example, 20 failures is one which is expected is 1 (or 100%) since the failure rate of transformers is 34. In other words, we are, statistically, 100 percent sure that there will be 20 failures in one year. The confidence level of getting 40 failures is around 10 percent which is in agreement with the data.

The probability density function of transformer failures is now calculated for a period of 5 years and the results are presented in a 3-D graphics given in Figure 4. The x-axis shows time in with steps of six months (10 is equivalent to 5 years). The y-axis indicates the number of transformer failures while the z-axis shows the probability of failure of exactly n-failures.

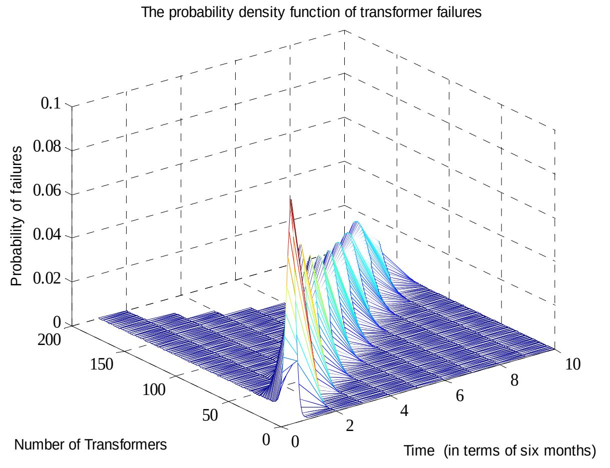

Figure 4. The probability density function of transformer failures in 3-D

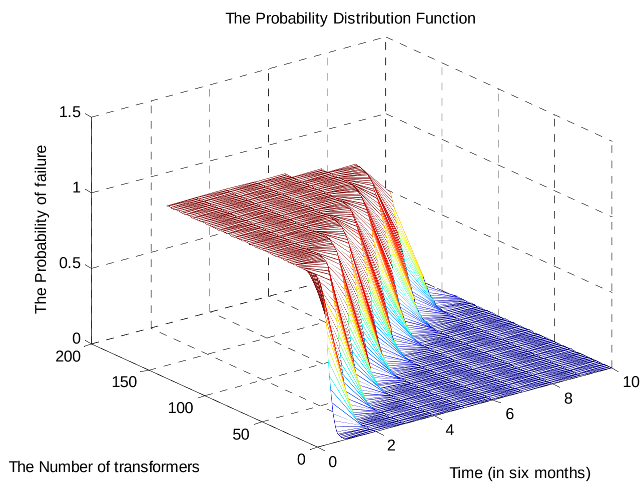

Figure 5. The probability distribution function of transformer failures in 3-D

The 3-D presentation of the probability density function helps to visualize transformer failures with respect to time. It can be seen from the figure 4 that probability of getting exactly 34 transformers in the first year is the highest.

Then the probability distribution of the transformer failures is calculated for a period of 5 year and the results are given in a 3-D graphics given in Figure 5.

The x-axis indicates time with steps of six months (10 is equivalent to 5 years). The y-axis shows the number of transformer failures while the z-axis provides the probability of getting exactly n-failures or less. It can be seen from the figure that on the average there would be around 150 transformer failures in five years which is expected and in agreement with the provided data.

The confidence level for transformer failures was also calculated for a time period of five years and the results are given in figure 6.

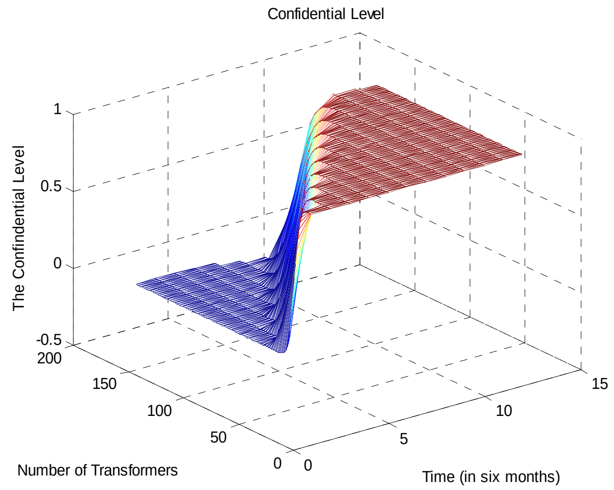

Figure 6. The confidence level of transformer failures in 3-D

The x-axis indicates time with steps of six months; y-axis indicates the number of transformer failures while the z-axis indicates the confidential level of occurrence of exactly n-failures or less. The results are as expected.

IV. CONCLUSIONS

The Poisson distribution function was used to predict the transformer failures in the grid of the power systems of the state utility company of Adiyaman district. The probability density function, probability distribution function and the confidential level of transformer failures were first calculated for a period of one year. The calculations were carried out for a period of five years.

The results were presented in 2-D and 3-D graphics using MATLAB simulation tool.

The results show that this method can be applied successfully to estimate the component failures in power systems in order to recruit repair crew, to schedule maintenance, to stock spares, and to analyze the overall system reliability.

The results provided here are preliminary and based on a number of assumptions which were mentioned in the introduction section. There are various parameters that need to be included in the analysis. For instance, the failure of a transformer may affect or initiate the failure of other transformers in the system, or the failure of other components (such as fuses, breakers etc.). Either man made or natural events may initiate the failure of a transformer. All of these parameters needs to be included for a complete analysis.

This study, based on the historical data of a power system, can be extended to analyze mean time to failure (MTTF) of components and mean time to repair (MTTR) of a certain component. Additionally the study can be extended to estimate the system availability and unavailability of the overall system for a certain period of time.

V. ACKNOWLEDGMENT

The authors would like to thank to Vice Director of the State Utility Company of the District of Adiyaman (TEDAS Adiyaman), Abdulbari ÜNSAL, for providing data used in this study.

VI. REFERENCES

1. M.J. Bollen, “Understanding Power Quality Problems voltage sags and Interruptions,” IEEE Press, New Jersey, 2000.

2. R. Ramakumar, “Engineering Reliability, Fundamentals and Applications,” Prentice Hall, New Jersey, 1993.

3. I. R. Miller, J.E. Freud, and R. Johnson, “Probability and Statistics for Engineers,” Prentice Hall, New Jersey, 1990.

4. K.S. Shanmugan and S.M. Breiphol, “Random Signals, Detection, Estimation and Data Analysis,” John Wiley, New York, 1988.

5. P.Z. Peebles JR, “Probability, Random Variables, and Random Signal Principles,” McGraw-Hill, New York, 1993.

6. H. Stark & J.W. Woods, “Probability, Random Processing and Estimation Theory for Engineers,” Prentice Hall, New Jersey, 1994.

7. H. Kumamoto & E.J. Henley, “Probabilistic Risk Assessment and Management for Engineers and Scientists,” IEEE Press, New York 1996.