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

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

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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 Adıyaman 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 k or fewer failures 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. The confidence level indicates the level of assurance of the failures.

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. It means that the failure of each transformer does not initiate the failure of another transformer in the same supply line. The failure of a transformer may affect the supply of another

one in the same supply line but this does not mean that it will initiate the failure of other transformers. In some special cases the failure of several or more transformers may affect each other but these cases are not included in this study.

It is also assumed that each transformer failure is repaired or the transformer itself is replaced 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.

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 43 transformer failures per year (based on the data collected from 2001 to 2004) (a sample of data collection sheet is given in appendix). 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 43 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 43 failures in one year is the highest which indicates that most probably there would be, on the average, 43 failures in a year.
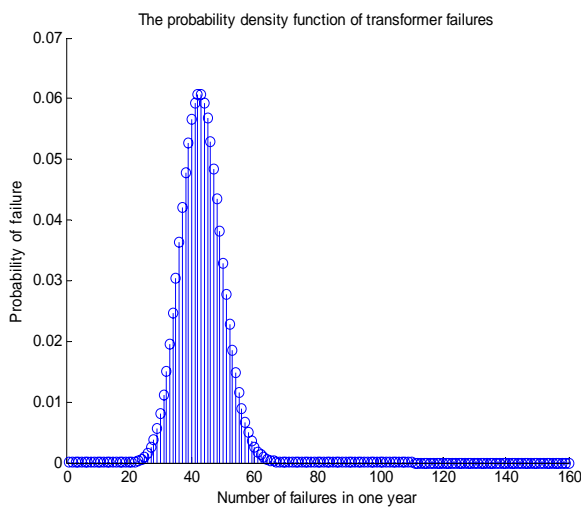

Figure 1. The probability density function of transformer failures

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 43 transformers or less is about 1 which is in agreement with the data.
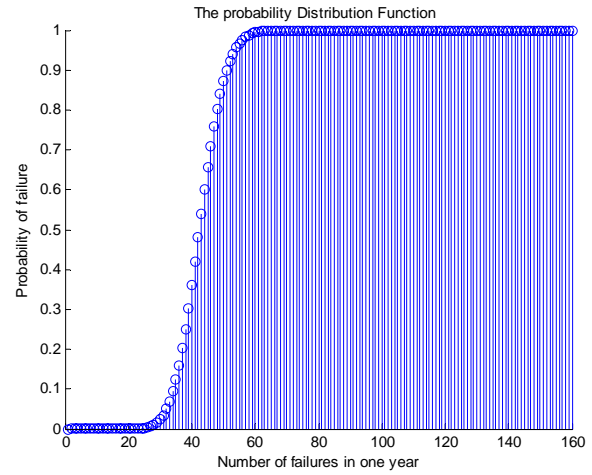

Figure 2. The probability distribution function of the transformer failures

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.
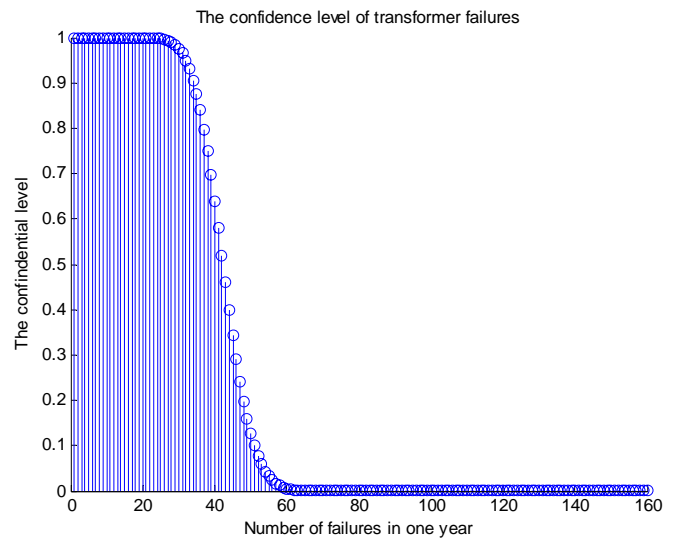

Figure 3. The confidence level of transformer failures

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 43. 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.
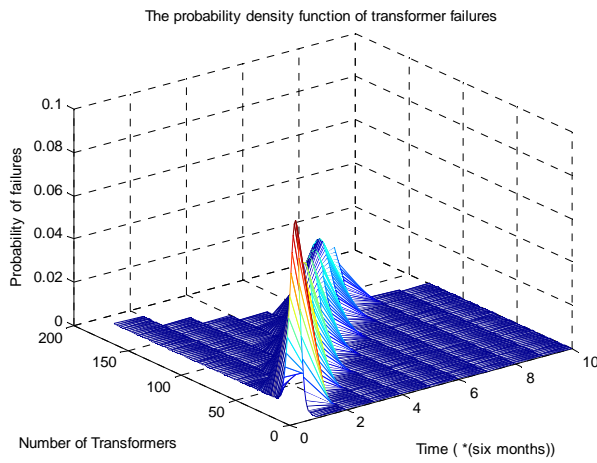

Figure 4. The probability density function of transformer failures in 3-D
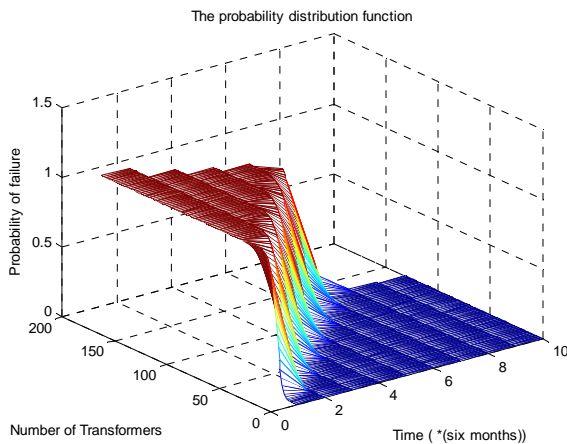

Figure 5. The probability distribution function of transformer failures in 3-D

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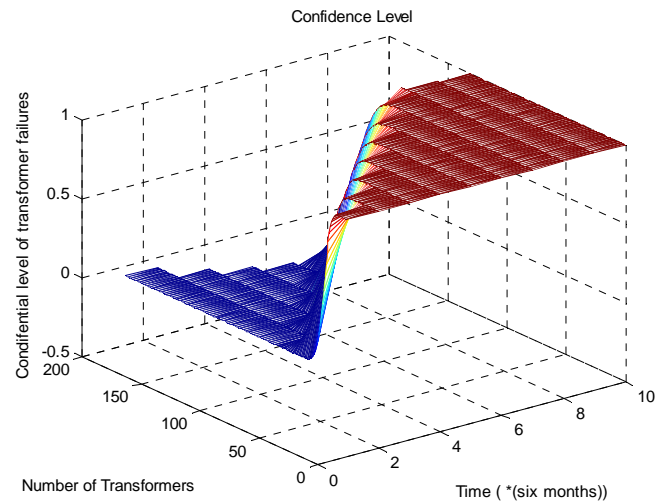
Figure 6. The confidence level of transformer failures in 3-D

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

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VII. APPENDIX
Data collection sheet

TEDAŞ ADIYAMAN E.D.M.

SİSTEM İŞLETME DAİRESİ BAŞKANLIĞI (Sistem İşletme Müdürlüğü)

O.G.-A.G. ARIZA BİLGİ FORMU

01.06.2004-30.06.2004

PUANT 104,4

		Adet	Saat
GERİLİM (kV)	ENERJİ KESİNTİSÜRESİ (Saat / Dakika)	34,5	
ORTA GERİLİM ARIZALARI		31,5	18 / 261
		15,8	
		10,5	
		6,3	
TOPLAM		436 / 380	

Component	Adet	Saat
TRAFO	3	42
İZALATÖR	2	9
İLETKEN	5	18
DİREK	5	39
ÖLÇÜ TR		
KESİCİ		
AYIRICI	1	9
KABLO	2	5
SİGORTA	35	98
PARAFUDR		
DİĞER	24	44
TOPLAM	18	261
PROGRAM LI/KESİKLI		

ALÇAK GERİLİM ARIZALARI

	Adet	Saat
TEL KOPUĞU	8	24
SİGORTA ATMASI	180	105
ŞALTER AÇMASI	35	73
KABLO ARIZASI	1	7
DİREK ARIZASI	2	15
ABONE ARIZASI	210	156
TOPLAM	436	380