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Design of Preventive Time and the Spare Part of Trafo Based on the ReliabilityAnalysis in PT PLN, Pasuruan Branch

Samsul Bachri M.

Department of Electrical Engineering, Faculty of Engineering, University of Jember, Indonesia

ABSTRACT

Operation time of PT PLN-Pasuruan Branch is 24 hours continuously. It give the impact of damage in trafo machine. The next impact is complain of electrical service users and it will cause the company income is not suitable with the hoped target. Therefore, the company make an effort yo gove the best service by guaranting the trafo machine can be well functioned and effectively operating such as a combination of preventive maintenance and damage improvement. By the maintenance, company carries out the change of spool and trafo oil in every spare time in order to decrease or delay the level of occured wearing out and damage. In addition, the maintenance is intended to get the low maintenance cost as well by carrying out the regularly and planned maintenance acitivity.
KEYWORDS: trafo, maintenance

INTRODUCTION

PT PLN-Pasuruan Branch has had area unit which includes Kraksaan, Probolinggo, Pasuruan City, Grati, Gondang W, Bangil, Pandaan, Prigen, and Sukorejo. Available energy total in 2001 was 359,239,420 Kwh and sold of 316,004,991 Kwh. PLN with its limitation fund for buying electrical and material, and the installing that is not attainable by society will cause there society or area mainly village has not been attainable by electrical facility.

Operation time of production in PLN-Pasuruan Branch is 24 hours continuously. It causes trafo machine is often damaged. The more increasing of electrical obstruction which is complained by electrical service user. Up to now, number of obstruction reached 89 with loss of Kwh was 91,636 which caused income level has not still fulfilled the hoped target of company. Therefore, there was difficulty in applying the schedule of maintenance because of suddent damage. Service and maintenance Department of PT PLN-Pasurusn Branch gives a policy by to carry out the maintenance by stressing in preventive maintenance. The service can be well carried out to the customers if there is no obstruction which is caused by trafo machine. However, one of the activities by PT PLN-Pasurusn Branch is to give the best service such as to guarantee the trafo machine so that is efectively functioned with good maintenance. PT PLN-Pasuruan Branch needs a combination between the preventive maintenance and improvement of obstruction. This activity intended to give good service to the customers for decreasing the obstruction by finding the preventive maintenance which can minimize the operational cost.

Based on the description as above, this study intended to know the suitable distribution as the life time distribution for spool and trafo oil; and to analyze the change time of spool and trafo oil based on the realibility theory which minimize total of cost.

MATERIALS AND METHODS

Maintenance

In implementation of production process, unavilable raw material will directly cause to the sustainability or stopping of production process in the company. Unavailable workers will cause the production process do not been carried out at this time such as there is no mechanical operator. Maintenance which is not carried out as a matter of course. will give more impact than the later of raw material or the less workers at the certain times, but because mechanical operator or company worker do not directly feel this condition so maintenance activity is less attended. Less attention of mechanical maintenance and production utility in the company will cause heavy damage of machine. Generally, the company worker will know or feel when the machines and production utilities have really been damaged or can not normally opespeed [1].

Definition of maintenance

Maintenance is all of the activities that is needed to hold a machine or utility in order to be remained in ready condition for operating and if there is damaged so there is made an effort to return back the machine or utility in good condition.

***Corresponding Author:** Samsul Bachri M., Department of Electrical Engineering, Faculty of Engineering, University of Jember, Indonesia, Email:samsulbachri941@yahoo.co.id

Efficiency in maintenance

Design on the firm maintenance of machine will decrease more damage speed, but it will cause the increasing of maintenance cost. On the contrary, if there is not carried out the good maintenance of machine, so the frequency of mechanical damage will become increase, because the better quality of maintenance will cause the more increasing of operational cost. Even the cost from time to time is missing because of the damage is smaller by the increasing of maintenance quality According to Lewis [2], this condition would be described as follow:

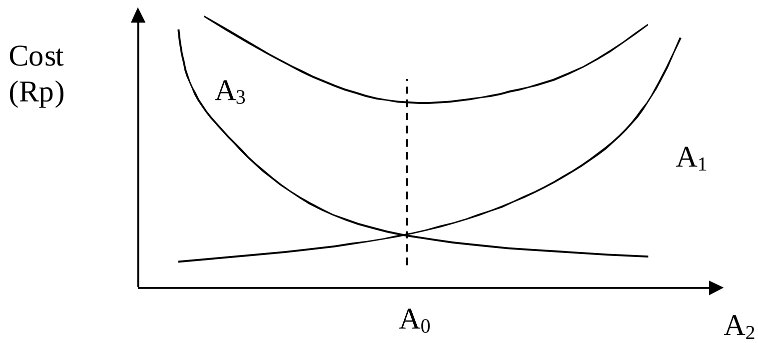

Figure 1 The relation between quality and cost of maintenance
(Note: A_1 = cost of preventive maintenance and damaged facility; A_2 = missing time cost due to the damage; A_3 = total cist of maintenance; A_0 = total cost of minimum maintenance)

A_0 is as optimum point which indicated the maintenance level which has to be given. Related to this case, there are two items that are needed to be attended in implementation the maintenance activity such as economical and technical problems. The economical problem includes as follow: 1) occured damage cost if there is no maintenance cost which is caused by occured damage even though it has carried out the maintenance; 2) maintenance cost which will spend by the utility; 3) maintenance and utility maintenance cost by number of loss because it is damaged during the production process; and 4) maintenance cost by the change cost if it is needed for changing. Technical problem which is related to the efforts for missing the possibility of stopping caused by unwell condition of production machine. The aim is to maintain normally production activity.

Reliability function

Reliability of sub-system or system is probability of the item for being not damaged during the period of t or more. The formulation of reliability due to time can be formulated as follow [3]:

$$R(\tau) = 1 - F(\tau) \quad (1)$$
$$R(\tau) = \int_{\tau}^{\infty} f(\tau)$$

Note:
R(t) = realiability
F(t) = comulative distribution function of failure probability
f(t) = probability density function

Failure speed

Failure speed (λ) is number of failure per-unit of time. Failure speed is expreesed as follow [4]:

$$\lambda(t) = \frac{f(t)}{R(t)} \quad (2)$$

Note:
$\lambda(t)$ = failure speed of hour
F(t) = failure probability
R(t) = total of operational time

Mean Time To Failure

The condition of a system is often expressed as the form of number which is presented as use time of system and notified as E(T) and it is often mentioned as Mean Time To Failure (MTTF). MTTF is onlu used in the component or utility which is often damaged and has to be changed with the new and good one. MTTF is formulated as follow [5]:

$$E(T) = MTTF = \int_0^{\infty} R(t) \quad (3)$$

Failure distribution

Failure distribution that is often used in reliability theory is as description of each distribution related to the probability density function, condition, failure speed, and MTTF [6].

Distribution of Weilbull

Probability density function of Weilbull is as follow:

$$f(t) = \frac{\alpha}{\beta}\left(\frac{t}{\beta}\right)^{\alpha-1} \exp\left(\frac{t}{\beta}\right)^{\alpha} \quad (4)$$

Note:

α = shaped parameter α ≥ 0

β = shaped parameter β ≥ 0

If the failure distribution of a component, sub-system, or system follows the distribution of Weilbull, so:

1) Reliability function of Weilbull distribution is as follow:

$$R(t) = exp\left[-\left(\frac{t}{\beta}\right)^{\alpha}\right] \quad (5)$$

2) Failure speed of Weilbull distribution is as follow:

$$\lambda(t) = \frac{\alpha}{\beta}\left[-\left(\frac{t}{\beta}\right)^{\alpha-1}\right] \quad (6)$$

3) MTTF= $\beta\left(1 + \frac{1}{\alpha}\right)$ (7)

Distribution of exponential

Probability of density function of exponential distribution as as follow;

$$f(t) = \lambda e^{-\lambda t} > 0{,}0, \lambda > 0 \quad (8)$$

If the failure distribution of a component, sub-system, or system follows the distribution of Exponential, so:

1) Reliability function of Exponential distribution is as follow:

$$R(t) = e^{-\lambda t} t \geq 0 \quad (9)$$

2) Failure speed of Exponential distribution is λ

3) $\text{MTTF} = \frac{1}{\lambda}$ (10)

Distribution of Normal

Normal distribution has two parameters that are mean (μ) and standard deviation (σ). Probability density function of Normal distribution is as follow:

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}}\ exp\left[-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2\right] \quad (11)$$

Note:

$\mu =$ mean and $\sigma =$ standard deviation

If the failure distribution of a component, sub-system, or system follows the distribution of Normal, so:

1) Reliability function of Normal distribution is as follow: $R\ (\tau) = \int_0^{\infty} \frac{1}{\sigma\sqrt{2\pi}} \exp -\frac{1}{2}\left(\frac{\tau-\mu}{\sigma}\right) dt = 1 - \emptyset\left(\frac{\tau-\mu}{\sigma}\right)$ (12)

2) Failure speed of Normal distribution is as follow:

$$\lambda\ (\tau) = \frac{\exp|(\tau-\mu^2/2\sigma^2)}{\int_0^{\infty} \exp|-(t-\mu)^2/2\sigma^2|dt} \quad (13)$$

3) $\text{MTTF} = \mu$ (14)

Distribution of Lognormal

Distribution of lognormal has two parameters which are almost the same as Normal distribution that are mean (μ) and deviation standard (σ). Probability desity function of Lognormal distribution is as follow:

$$f(\tau) = \frac{1}{(\tau-\theta)\sqrt{2\pi\sigma}} \exp\left[-\frac{[In(\tau-\theta)-\mu]^2}{2\sigma^2}\right] \quad (15)$$

Note:

μ = mean and σ = deviation standard

Model of failure speed

The function of failure speed: λ (t), will change along the age of population system or component. Based on the experiment and experience, failure speed of a component will follow the base pattern as in Figure 2 below.

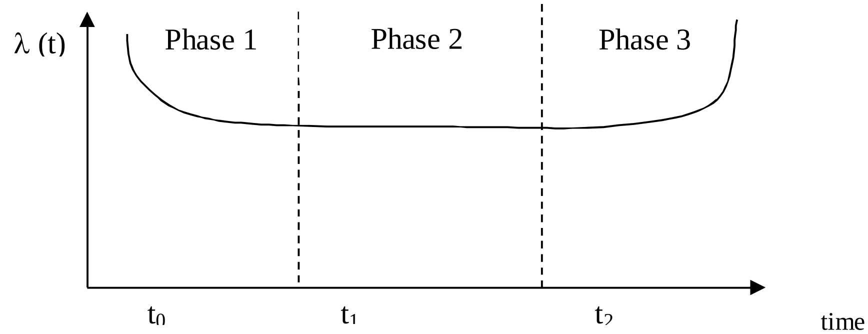

Figure 2. The pattern of failure speed

Figure 2 shows that phase 1 is influenced by distribution of Weibull and Gamma' pahse 2 is influenced by distribution of Weibull, Gamma, and exponential; and phase 3 is influenced by distribution of Normal and Weibull. Therefore, the suitable distribution of the three phases is Weibull.

Testing of goodness of fit on distribution

Data of failure time has to be formerly evaluated so that the reliability theory can be accurately used. The evaluation can be carried out by following the steps as follow [7]:

1. To calculate variate coefficient (s) of data. If s is close to 1, the distribution is close to exponential, if s > 1, the distribution follows Gamma distribution, and if s < 1, the distribution close to Weibull.
2. To use the test of Kolmogorof-Smirnov. This method is to compare the empirical and theoritical data. F_n (x) is empirical distribution function and F(x) is the theoriticak one, and then to calculate the difference between the two functions as follow; $D_n = Max \left|\left(F_{n(x)} - F(x)\right)\right|$ (16)
3. If the distribution is exponential with λ is unknown, so the hipothesis of 0 is not accepted if

$$\left[D_n - \frac{0{,}2}{n}\right]\left[\sqrt{n} + 0{,}2 + \frac{0{,}5}{\sqrt{n}}\right] > C_{1-\alpha} \quad (17)$$

Change of time

Generally, utility damage is suddently occured and this utility has to be changed. The damage is not hoped, so that it is assumed to be changed because the damage is more expensive than the preventive change. Total of operational cost of a component after having operated in the certain time [1] is as follow:

$$TC : N_pC_p + N_fC_f \quad (18)$$

Note:
N_p : number of preventive component change
N_f : number of damaged component
C_p : preventive cost
C_f : damaged cost

Total of changed components is as follow:

$$N = N_p + N_f \quad (19)$$

Generally, total of operational time is higher that Mean Time Between Replacement (MTBR), so it can be estimated as follow:

$$N \approx \frac{t}{MTBR} \quad (20)$$

$$N \approx \frac{\tau}{\int_0^T R(t)dt} \quad (21)$$

Because of component total of N, in the period of t, and reliability of R(t), so estimation of well funtioned component is as follow:

$$N_p = N\ R(T) = \frac{tR\ (T)}{\int_0^T R(t)dt} \text{ and } N_p = N\ \{1 - R\ (T)\} = \frac{t\{1-R(T)\}}{\int_0^T R(t)dt}$$

Total of operational cost can be expressed as follow: :

$$TC = \frac{tR(T)}{\int_0^T R(t)dt} c_p + \frac{\{1-R(T)\}^1}{\int_0^T R(t)dt} c_f \quad (22)$$

For determining the interval of change time which can minimize total of operational cost, it is used standard calculus method such as $\frac{dTC}{dT} = 0$. and $\lambda(t) = \frac{f(t)}{R(t)}$, then it is obtained as follow:

$$R(T) + \lambda(T) \int_0^T R(t)dt - 1 = \frac{C_P}{C_f - C_p} \quad (23)$$

For Weibull distribution of 3 parameters, it is known that:

$$R(t) = e^{1-\left(\frac{t-\gamma}{\beta}\right)^\alpha}$$

$$\lambda(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}$$

The result is

$$e^{1-\left(\frac{t-\gamma}{\beta}\right)^\alpha} + \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1} \int_0^T \left(\frac{t-\gamma}{\beta}\right)^\alpha dt - 1 = \frac{C_P}{C_f - C_p} \quad (24)$$

For making easier the calculation process, it can be used the approach as follow:

$$1 - \left(\frac{t-\gamma}{\beta}\right)^\alpha + \cdots\cdots + \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}\left[T - \frac{1}{\alpha+1}\left(\frac{t-\gamma}{\beta}\right)^{\alpha+1} + \cdots\cdots\right] - 1 = \frac{C_P}{C_f - C_p}$$

By only attending the part of the formula which includes T^m, it is obtained as follow:

$$(\alpha - 1)\left(\frac{T-\gamma}{\beta}\right)^\alpha = \frac{C_P}{C_f - C_p} \text{ or } T \approx \gamma + \beta\left[\frac{1}{\alpha-1}\frac{C_P}{C_f - C_p}\right]^{\frac{1}{\alpha}}$$

2.30

For Weilbull distribution of 2 parameters (γ = 0), it is obtained:

$$T \approx \beta\left[\frac{1}{\alpha-1}\frac{C_P}{C_f - C_p}\right]^{\frac{1}{\alpha}} \quad (25)$$

RESULTS AND DISCUSSION

Analysis of Trafindo trafo due to the time interval of spool change

Time interval of change is obtained in the part of maintenance on January 2001 until March 2004, the result was presented as in Table 1 below.

Table 1. Rank of suitable distribution for time interval of spool change

Distribution	Rank
Exponential of 1 parameter	6
Exponential of 2 parameters	5
Weibull of 2 parameters	1
Weibull of 3 parameters	4
Normal	2
Log Normal	3

Mean time of change

$$MTTF = \beta.\Gamma\left(1 + \frac{1}{\alpha}\right)$$

$$MTTF = 367{,}0269.\Gamma\left(1 + \frac{1}{18{,}2550}\right)$$

$$MTTF = 367{,}0269(0{,}97350)$$

$$MTTF = 357{,}30$$

Analysis of Trafindo trafo due to the time interval of trafo oil change

Rank of suitable distribution for time interval of trafo oil change of Trafindo trafo is presented as in Table 2 below.

Table 2 Rank of suitable distribution for time interval of trafo oil change

Distribution	Rank
Exponential of 1 parameter	6
Exponential of 2 parameters	5
Weibull of 2 parameters	4
Weibull of 3 parameters	1
Normal	2
Log Normal	3

Based on the Table 2, the suitable distribution for change time of trafo oil was Weibull of 3 parameters with the parameter estimation as follow: α = 2.6503, β = 153.305, and γ = 39.3939. The probability density function was as follow:

$$f(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1} exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{á-1}\right\}$$

$$f(t) = \frac{2,6503}{153,305}\left(\frac{t-39,9395}{153,305}\right)^{2,6503-1} exp\left\{-\left(\frac{t-39,9395}{153,305}\right)^{2,6503-1}\right\}$$

The reliability function was:

$$R(t) = exp\left\{\left(\frac{t-\gamma}{\beta}\right)^{\alpha}\right\}$$

$$R(t) = exp\left\{\left(\frac{t-39,9395}{153,305}\right)^{2,6503}\right\}$$

The damage speed function was:

$$\lambda(t) = \frac{\alpha}{\beta}\left(\frac{t-ã}{\beta}\right)^{\alpha-1}$$

$$\lambda(t) = \frac{2,6503}{153,305}\left(\frac{t-39,9395}{153,305}\right)^{2,6503-1}$$

Mean time of change was:

$$MTTF = \gamma + \beta.\Gamma\left(1 + \frac{1}{\alpha}\right)$$

$$MTTF = 39,9395 + 153,305.\Gamma\left(1 + \frac{1}{2,6503}\right)$$

$$MTTF = 176,89$$

Analysis of Unindo trafo due to the time interval of spool change

Rank of suitable distribution for the time interval of spool change of Unindo trafo was presented as in Table 3 below.

Table 3 Rank of suitable distribution for time interval of spool change

Distribution	Rank
Exponential of 1 parameter	6
Exponential 2 parameters	5
Weibull of 2 parameters	2
Weibull of 3 parameters	1
Normal	3
Log Normal	4

Table 3 presented that the suitable distribution for time data of spool change was Weibull of 2 parameters with the estimation of parameters as follow: α = 8.057, β = 157.2507, and γ = 227.1. The probability density function was as follow:

$$f(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1} exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}\right\}$$

$$f(t) = \frac{8,057}{157,205}\left(\frac{t-227,1}{157,205}\right)^{8,057-1} exp\left\{-\left(\frac{t-227,1}{157,205}\right)^{8,057-1}\right\}$$

The reliability function was as follow;

$$R(t) = exp\left\{-\left(\frac{t-y}{\beta}\right)^{\alpha}\right\}$$

$$R(t) = exp\left\{-\left(\frac{t-227,1}{157,205}\right)^{8,057}\right\}$$

The damaged speed function was as follow:

$$\lambda(t) = \frac{\alpha}{\beta}\left(\frac{t-y}{\beta}\right)^{\alpha-1}$$

$$\lambda(t) = \frac{8,057}{157,2507}\left(\frac{t-227,1}{157,2507}\right)^{8,057-1}$$

The mean time of change was as follow:

$$MTTF = \gamma + \beta.\Gamma\left(1 + \frac{1}{\alpha}\right)$$

$$MTTF = 227{,}1 + 157{,}2507.\Gamma\left(1 + \frac{1}{8{,}057}\right)$$
$$MTTF = 375{,}48$$

Analysis of Unindo trafo due to the time interval of trafo oil change

Rank of suitable distribution for the time interval of trafo oil change of Unindo trafo was presented as in Table 4 below.

Table 4. Rank of suitable distribution for time interval of trafo oil change

Distribution	Rank
Exponential of 1 parameter	6
Exponential 2 parameters	5
Weibull of 2 parameters	4
Weibull of 3 parameters	1
Normal	2
Log Normal	3

Table 4 showed that the suitable distribution for change time of trafo oil was weibull of 3 parameters with the estimation of parameters as follow: α = 3.5006, β = 56.8377, and γ = 120,28. The probability density function was as follow:

$$f(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1} \quad exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{\acute{a}-1}\right\}$$
$$f(t) = \frac{3{,}5006}{56{,}8377}\left(\frac{t-120{,}28}{56{,}8377}\right)^{3{,}5006-1} \quad exp\left\{-\left(\frac{t-120{,}28}{56{,}8377}\right)^{3{,}5006-1}\right\}$$

The reliability function was as follow::

$$R(t) = exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{\alpha}\right\}$$
$$R(t) = exp\left\{-\left(\frac{t-120{,}28}{56{,}8377}\right)^{3{,}5006}\right\}$$

The damage speed function was as follow:

$$\lambda(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}$$
$$\lambda(t) = \frac{3{,}5006}{56{,}8377}\left(\frac{t-120{,}28}{56{,}8377}\right)^{3{,}5006-1}$$

The mean time of change was as follow:

$$MTTF = \gamma + \beta.\Gamma\left(1 + \frac{1}{\alpha}\right)$$
$$MTTF = 120{,}28 + 56{,}8377.\Gamma\left(1 + \frac{1}{3{,}5006}\right)$$
$$MTTF = 171{,}38$$

Analysis of Starlite trafo due to the time interval of spool change

Rank of suitable distribution for the time interval of trafo oil change of Starlite trafo was presented as in Table 5 below.

Table 5: Rank of the suitable distribution for time interval of spool change

Distribution	Rank
Exponential of 1 parameter	5
Exponential of 2 parameters	4
Weibull of 2 parameters	3
Weibull of 3 parameters	1
Normal	6
Log Normal	2

Table 5 showed that the suitable distribution for time data of trafo oil was Weibull of 3 parameters with the estimation of parameters as follow: α = 1.3417, β = 321.9375, and γ = 36.9208. The probability density function was as follow:

$$f(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1} \quad exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}\right\}$$

$$f(t) = \frac{1,3417}{321,5375}\left(\frac{t-36,9208}{321,5375}\right)^{1,3417-1} \quad exp\left\{-\left(\frac{t-36,9208}{321,5375}\right)^{1,3417-1}\right\}$$

The reliability function was as folloiw:

$$R(t) = exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{\alpha}\right\}$$

$$R(t) = exp\left\{-\left(\frac{t-36,9208}{321,5375}\right)^{1,3417}\right\}$$

The damage speed function was as follow:

$$\lambda(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}$$

$$\lambda(t) = \frac{1,3417}{321,5375}\left(\frac{t-36,9208}{321,5375}\right)^{1,3417-1}$$

The mean time of change was as follow:

$$MTTF = \gamma + \beta.\Gamma\left(1 + \frac{1}{\alpha}\right)$$

$$MTTF = 36,9208 + 321,5375.\Gamma\left(1 + \frac{1}{1,3417}\right)$$

$$MTTF = 332,08$$

Analysis of Starlite trafo due to the time interval of trafo oil change

Rank of suitable distribution for time interval of trafo oil for Starlite was presented as in Table 6.

Table 6. Rank of suitable distribution for time interval of trafo oil change

Distribution	Rank
Exponential of 1 parameter	6
Exponential of 2 parameters	4
Weibull of 2 parameters	5
Weibull of 3 parameters	1
Normal	3
Log Normal	2

Table 6 presented that the suitable distribution for change time of trafo oil was Weibull of 3 parameters with the estimation of parameter as follow: α = 1.7274, β = 133.3975; and γ = 28,6639. The probability density function was as follow:

$$f(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1} \quad exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}\right\}$$

$$f(t) = \frac{1,7274}{133,3975}\left(\frac{t-28,6639}{133,3975}\right)^{1,7274-1} \quad exp\left\{-\left(\frac{t-28,6639}{133,3975}\right)^{1,7274-1}\right\}$$

The reliability function was as follow:

$$R(t) = exp\left\{-\left(\frac{t-\gamma}{\beta}\right)^{\alpha}\right\}$$

$$R(t) = exp\left\{-\left(\frac{t-28,6639}{133,3975}\right)^{1,7274}\right\}$$

The damage speed function was as follow:

$$\lambda(t) = \frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}$$

$$\lambda(t) = \frac{\lambda}{133,3975}\left(\frac{t-28,6639}{133,3975}\right)^{1,7274-1}$$

Mean time of change was as follow:

$$MTTF = \gamma + \beta.\Gamma\left(1 + \frac{1}{\alpha}\right)$$

$$MTTF = 28,6639 + 133,3975.\Gamma\left(1 + \frac{1}{1,7274}\right)$$

$$MTTF = 147,71$$

Analysis of cost

In preventive management there are 2 kinds of cost such as subtitution and cost because or component damage. Substitution cost included worker cost and spare part rate. Damage cost included worker cost and opportunity cost of damage.

Analysis on time interval of spool change

Analysis on optimal time interval of change was carried out for each component as follow:

- Analysis on change time of Trafindo trafo:
  - $T \approx \beta \left[\frac{1}{\alpha-1} \cdot \frac{Cp}{Cf-Cp}\right]^{\frac{1}{\alpha}}$
  - The value of oarameters: α=18,2550; β=367,0269
  - Cp=Rp. 20.876.666,66; Cf=8.876,666,66
  - $T \approx \beta \left[\frac{1}{17{,}250} \cdot \frac{8.876{,}666{,}66}{20.876.666{,}66-8.876{,}666{,}66}\right]^{\frac{1}{18{,}2550}}$
  - T ~ 380 days
- Analysis on change time of Urindo trafo:
  - $T \approx \gamma + \beta \left[\frac{1}{\alpha-1} \cdot \frac{Cp}{Cf-Cp}\right]^{\frac{1}{\alpha}}$
  - The value of parameters : α=9,05725; β=157,250661; γ=227,1
  - $T \approx 227{,}1 + 157{,}250661 \left[\frac{1}{7{,}05725} \cdot \frac{8.876{,}666{,}66}{20.876.666{,}66-8.876{,}666{,}66}\right]^{\frac{1}{9{,}05725}}$
  - T ~ 346.02 days ~ 346 days
- Analysis on change time of starlite trafo:
  - $T \approx \gamma + \beta \left[\frac{1}{\alpha-1} \cdot \frac{Cp}{Cf-Cp}\right]^{\frac{1}{\alpha}}$
  - The values of parameters : α=1,3417; β=36,92081 dan γ=321,9375
  - $T \approx 321{,}9375 + 36{,}92081 \left[\frac{1}{0{,}3417} \cdot \frac{8.876{,}666{,}66}{20.876.666{,}66-8.876{,}666{,}66}\right]^{\frac{1}{1{,}3417}}$
  - T ~ 387.97 days ~ 388 days

Analysis on time interval of trafo oil

- Analysis on change time of Trafindo trafo
  - $T \approx \gamma + \beta \left[\frac{1}{\alpha-1} \cdot \frac{Cp}{Cf-Cp}\right]^{\frac{1}{\alpha}}$
  - The value of parameters : α=2,65028; β=39,3939 and γ=153,305
  - $T \approx 153{,}305 + 39{,}3939 \left[\frac{1}{1{,}65028} \cdot \frac{8.876{,}666{,}66}{20.876.666{,}66-8.876{,}666{,}66}\right]^{\frac{1}{2{,}65028}}$
  - T ~ 181.97 days ~ 182 days

- Analysis on change time of Urindo trafo
  - $T \approx \gamma + \beta \left[\frac{1}{\alpha-1} \cdot \frac{Cp}{Cf-Cp}\right]^{\frac{1}{\alpha}}$
  - The value of parameters : α=3,50059; β=56,8376 and γ=120,28
  - $T \approx 120{,}28 + 56{,}8376 \left[\frac{1}{3{,}50059} \cdot 0{,}431\right]^{\frac{1}{3{,}50059}}$
  - T ~ 164.12 days ~ 164 days

- Analysis on change time of Starlite trafo
  - $T \approx \gamma + \beta \left[\frac{1}{\alpha-1} \cdot \frac{Cp}{Cf-Cp}\right]^{\frac{1}{\alpha}}$
  - The value of parameters : α=1,72738; β=28,6629 and γ=133,3975
  - $T \approx 133{,}3975 + 28{,}6629 \left[\frac{1}{1{,}72738} \cdot 0{,}431\right]^{\frac{1}{1{,}72738}}$

- T ~ 154.6 days ~ 155 days

Analysis on total of change time

Change time was determined based on the observation of cost for presenting the profit. Field data was collected by the end of 3 years (January 2001 until December 2003) and it was found more damaged components as described in Table 7 below.

Table 7 Number of occured damage in 3 years:

No.	Merk	Component	Number of damaged component in 3 years	Number of damaged component per-year
1	Trafindo	Spool	4	1,33
		Trafo oil	7	2,33
2	Urindo	Spool	5	1,67
		Trafo oil	6	2
3	Starlite	Spool	4	1,33
		Trafo oil	6	2

For example, there would be calculated an economy cost for spool of Trafindo trafo. The cost of change before preventive program was as number of damage multiplied by number of change or 1.33 x Rp. 20.876.666,66 = Rp. 27.765.966,66

CONCLUSION

Based on the analysis as above, it could be concluded as follow: 1) The used age distribution for change of spool for Trafindo trafo was suitable to the Weibull distribution of 2 parameters with the usage time of 308 days, but Unindo trafo and Starlite trafo were suitable to Weibull distribution of 3 parameters with each the usage time of 346 days and 388 days; 2) The used age distribution for each merk of trafo was suitable to the Weibull distribution of 3 parameters with the usage time for Trafindo, Unindo, and Starlite was each of 182 days, 164 days, and 155 days; 3) By being the planned change program due to the change time and related cost, it was obtained an economy cost because there was planned change program. The comparison with and without planned program was as follow:

- Trafindo trafo:
  Spool Rp. 16.036.187,86 (57.76%)
  Tarfo oil Rp. 27.028.526,24 (67.00%)
- Unindo trafo:
  Spool Rp. 24.518.253,1 (70.32%)
  Trafo oil Rp. 11.310.256,66 (32.67%)
- Starlite trafo:
  Spool Rp. 7.613.256,87 (27.42%)
  Trafo oil Rp. 8.670.245,66 (25.04%)

Based on the time of preventive maintenance, it was seen that more oil changer of trafo would cause longer age of spool. Therefore, for increasing the reliability of trafo, it was suggested to more often change the trafo oil . The more analysis can be carried out by making efficiency in the performance of maintenance, so that PLN Pasuruan Branch is needed to develop accurately the manner of change time recording because really and accurate of analysis result is very depended on the data recoeding of change time.

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