Full life-cycle analysis of electrical equipment Transformer

Reliability Engineering _ Homework

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Task 1: Choose a product or system based on a real world example of your choice.

- **- Transformers are the most important equipment in the distribution system for delivering power to consumers.**

- **Failures in power transformers can lead to power outages affecting thousands of customers, while failures in distribution transformers may only impact a small number of customers.**

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Lifetime Estimation of Electrical Equipment in Distribution system using Modified 3-Parameter Weibull Distribution

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***Abstract*—Lifetime and reliability estimation of distribution system components are very crucial for reliable operation of the distribution system. Reliability of the distribution system depends on the reliability of individual components. The distribution system equipment experiences three different types of failures i.e. infant mortality failures, random failures and aging failures. Infant mortality failures will decrease with time, random failures are induced by the external event and its occurrence is constant and random in nature throughout the life of the component. The aging failures increases with time over the useful lifetime of the equipment due to degradation of electrical and mechanical durability. The impact of aging on electrical equipment is modelled by using the failure history of the equipment. The strength of component reduces due to failures, this phenomenon is considered for lifetime estimation of equipment. This paper presents a 3-parameter Weibull distribution function with varying shape parameter for lifetime estimation. The Weibull parameters are determined by using historical failure data and particle swarm optimization. The proposed model is applied to the equipment of the practical Indian distribution system.**

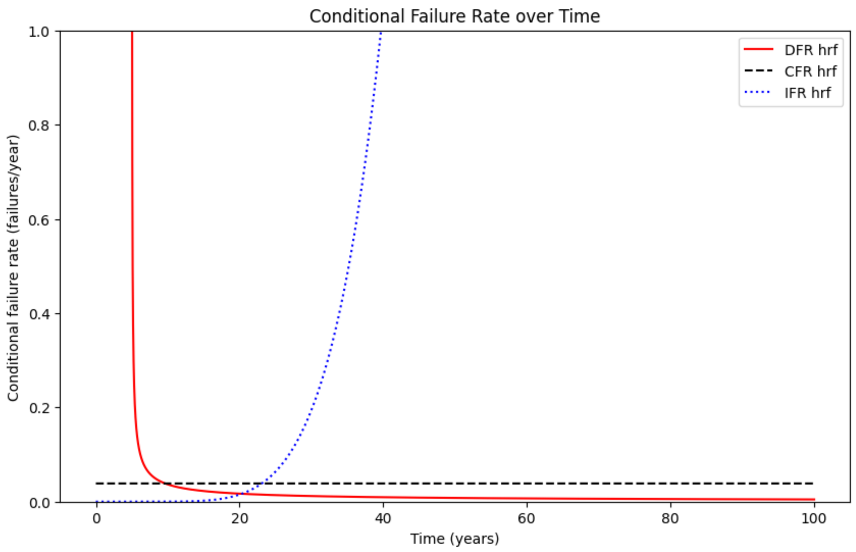
maintenance cost will affects the component lifetime. For reliability evaluation of distribution system, component operating and failure states were modelled by using exponential distribution [4], which is giving the constant hazard rate with time. The component was considered as good as new after restoring from failures. But in actual practice, they have an aging effect as the equipment is in continues operation. The component failure rate is not constant for the whole lifetime, but rises over the years according to the bathtub curve. The rate of failures was increasing with time over the useful life of cables, circuit breakers, and transformers [5] - [7]. The effect of insulating materials and oil on transformers aging failures was discussed [3]-[8].

The component aging effect on power system reliability was discussed in [9]. The risk management process was employed to judge the maintenance and investment priorities [10]. The electrical components perform both technical as well as economical functions in distribution systems. Three types of lifetimes are specified in [11], physical lifetime,

Reddy, Galiveeti Hemakumar, et al. "Lifetime Estimation of Electrical Equipment in Distribution system using Modified 3-Parameter Weibull Distribution." *2021 International Conference on Design Innovations for 3Cs Compute Communicate Control (ICDI3C)*. IEEE, 2021.

Task 1: Choose a product or system based on a real world example of your choice.

Electrical component	β			α	γ
	DFR	CFR	IFR		
Transformer	0.1	1	6	25.9	5



- We Found the hyper parameter of electrical equipment system that flows on Weibull Distribution.

- We selected the transformer electrical equipment and used this parameter for generating data.

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Task 1: Choose a product or system based on a real world example of your choice.

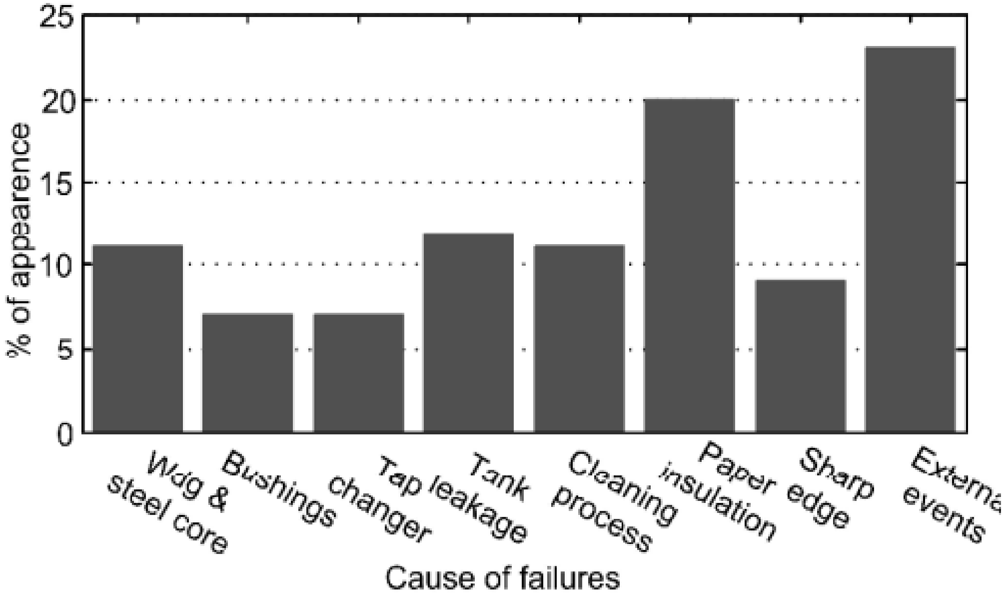


Fig. 2. Causes of transformers failure

- The causes of transformer failures can be divided into four main categories: assembly process, cleaning process, raw materials, and external events.

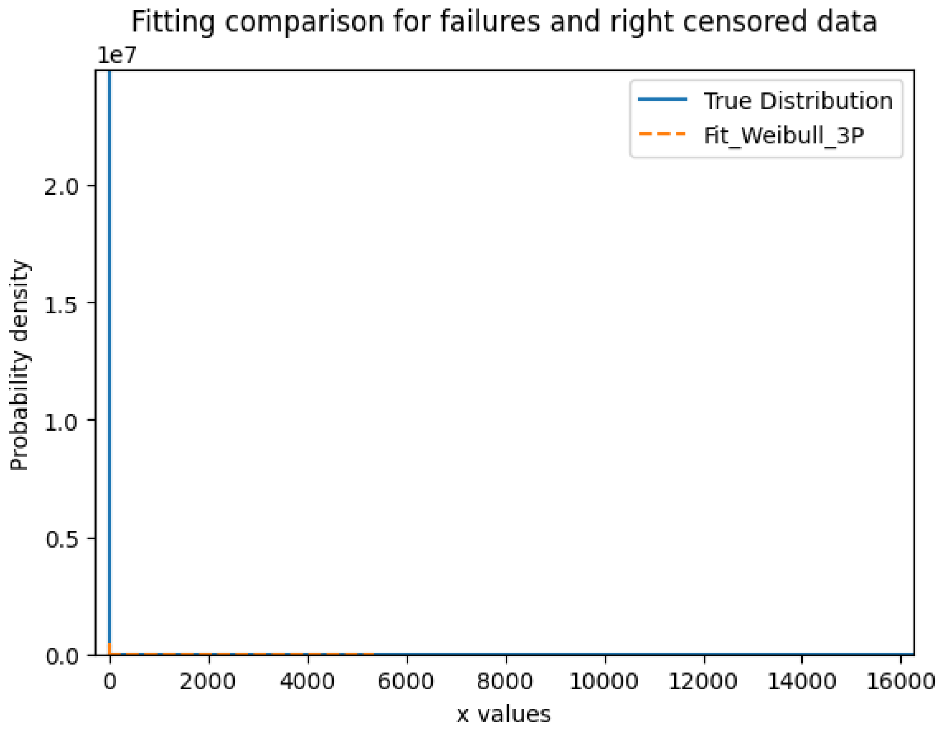
Task 2: Look for or generate data for each phase of the bath-tube curve.

- **We used this hyper parameter of this systems Weibull distribution and generated data of each bath-tube curve sections.**
- **We set the threshold to 30 and distributed the failed data and the collected data.**
- **We generated 100 sample data for each phase.**

Task 2: Look for or generate data for each phase of the bath-tube curve.

Infant Mortality Period

In the beginning, the failure rate is high due to manufacturing defects, poor quality materials, early wear, or other issues that become apparent soon after a product is first used



Alpha: 25.9

Beta: 0.1

Gamma: 5

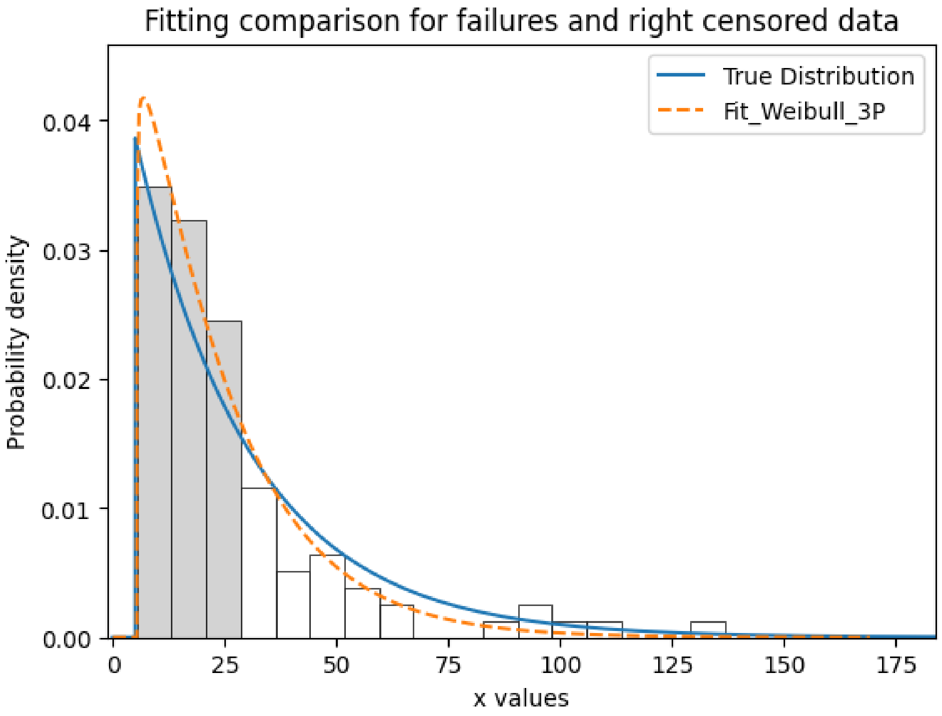
<Hyperbolic>

Task 2: Look for or generate data for each phase of the bath-tube curve.

Useful Life Period

After the initial period, the product enters a phase of reliable performance with a low and constant rate of failure

This is the period where the product performs as expected, with failures occurring at a predictable and steady rate



Alpha: 25.9

Beta: 1

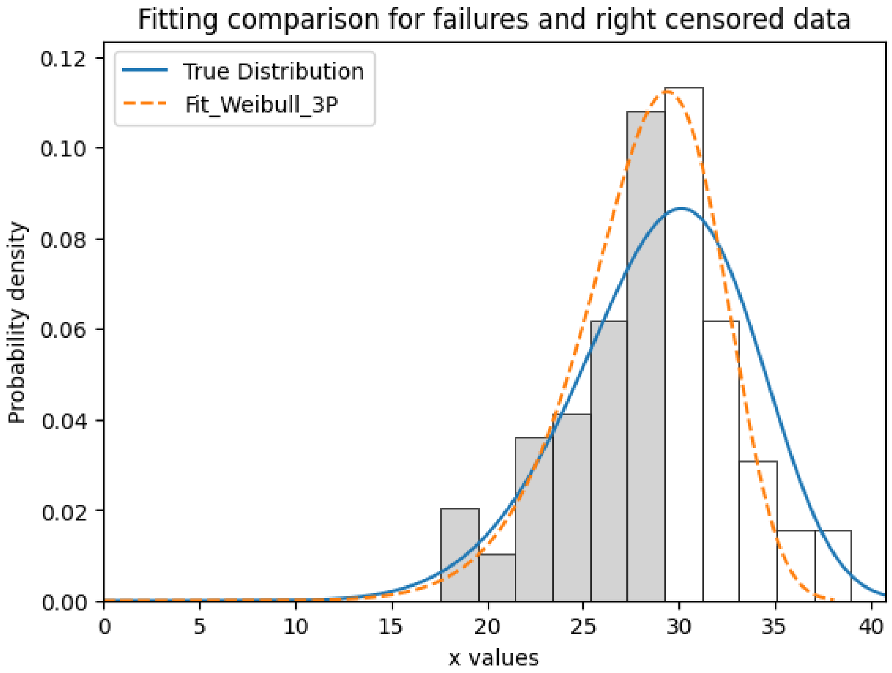
Gamma: 5

<Constant>

Task 2: Look for or generate data for each phase of the bath-tube curve.

Wear-Out Period

Over time, wear and tear, aging components, and other factors lead to an increasing failure rate. This phase signifies that the product is reaching the end of its useful life, and failures become more frequent as parts degrade or exceed their life expectancy.



Alpha: 25.9

Beta: 6

Gamma: 5

<Polynomial>

Task 3: Look for or generate data for maintainability

$$MTBF = \frac{\alpha}{\beta} \cdot \Gamma\left(1 + \frac{1}{\beta}\right)$$

Alpha: 25.9	Alpha: 25.9	Alpha: 25.9
Beta: 0.1	Beta: 1	Beta: 6
Gamma: 5	Gamma: 5	Gamma: 5
<Hyperbolic>	<Constant>	<Polynomial>

```python
from scipy.special import gamma

def calculate_mtbf(shape, scale):
    return scale * gamma(1 + 1/shape)

# Example usage
shape_parameter = 25.9  # Example shape parameter
scale_parameter = 0.1
  # Example scale parameter

mtbf = calculate_mtbf(shape_parameter, scale_parameter)
print(mtbf)
```

```
0.09791379698759407
```

```python
from scipy.special import gamma

def calculate_mtbf(shape, scale):
    return scale * gamma(1 + 1/shape)

# Example usage
shape_parameter = 25.9  # Example shape parameter
scale_parameter = 1
  # Example scale parameter

mtbf = calculate_mtbf(shape_parameter, scale_parameter)
print(mtbf)
```

```
0.9791379698759407
```

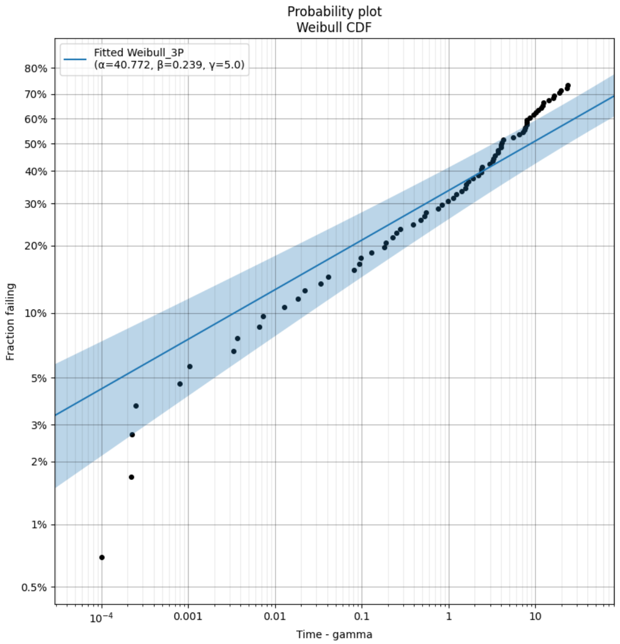
```python
from scipy.special import gamma

def calculate_mtbf(shape, scale):
    return scale * gamma(1 + 1/shape)

# Example usage
shape_parameter = 25.9  # Example shape parameter
scale_parameter = 6
  # Example scale parameter

mtbf = calculate_mtbf(shape_parameter, scale_parameter)
print(mtbf)
```

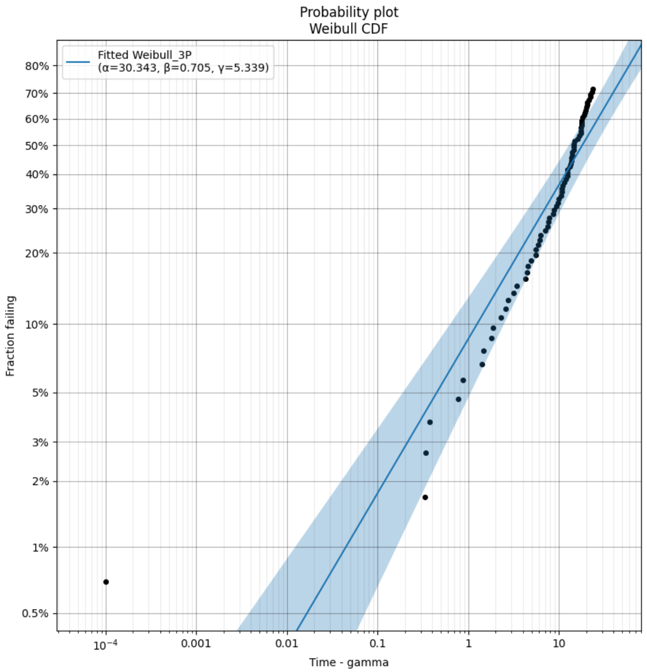
```
5.874827819255645
```

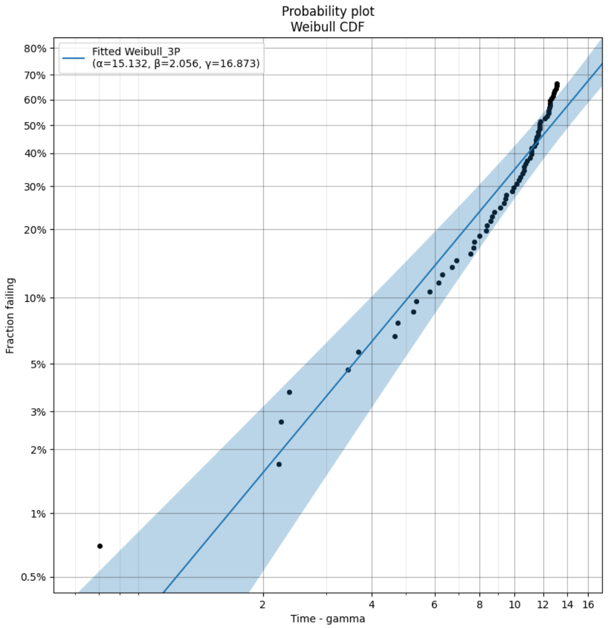
- As we know the MTBF formula and alpha, beta, we can know the maintainability time of this system.

- Substituting the alpha beta gamma value into the equation for each section, the MTBF in that section can be found, and the maintenance time can be found through this.

Task 4: Develop a reliability model for each phase & maintainability

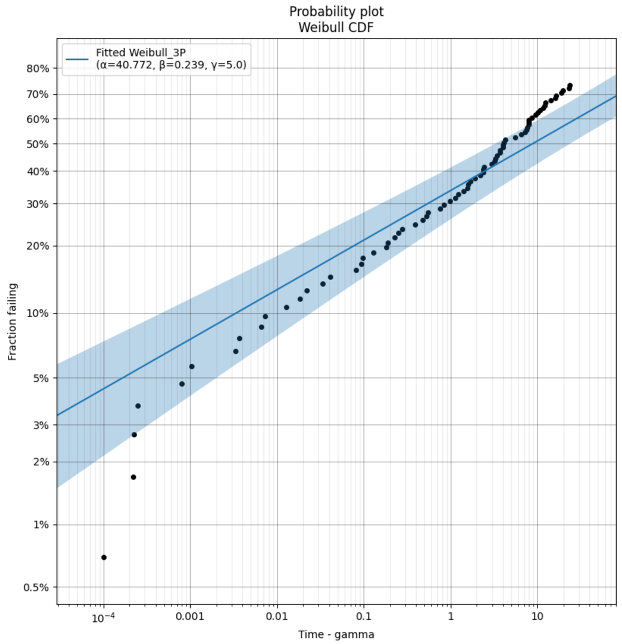






- **We developed a reliability model for each phase of the bath-tube curve via using each generated data.**
- **A Weibull probability plot is used to test whether the data follows a Weibull distribution.**
- **The linear appearance on the Weibull probability plot indicates that the data follows a Weibull distribution**

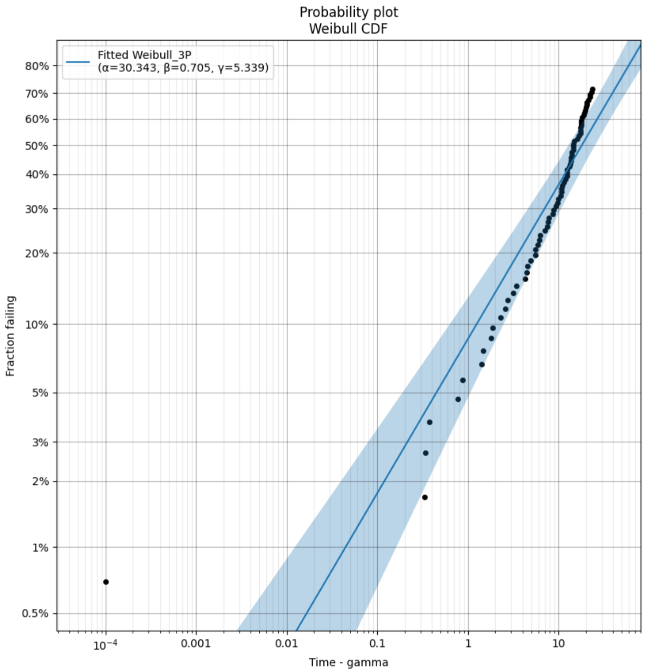
Task 5: Estimate the parameters of the chosen model for each phase & maintainability



Alpha: 40.7722

Beta: 0.239422

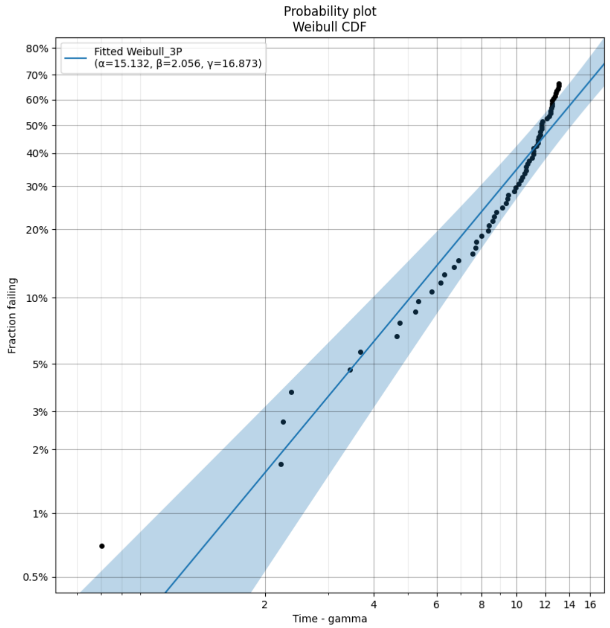
Gamma: 4.99991



Alpha: 30.3429

Beta: 0.705368

Gamma: 5.33926



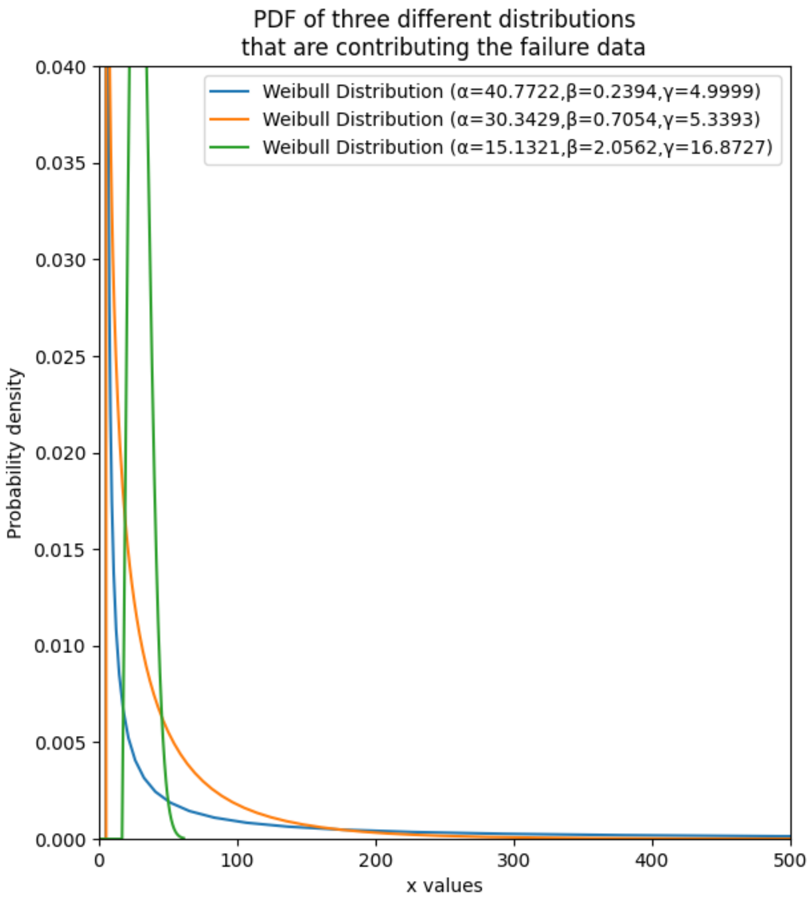
Alpha: 15.1321

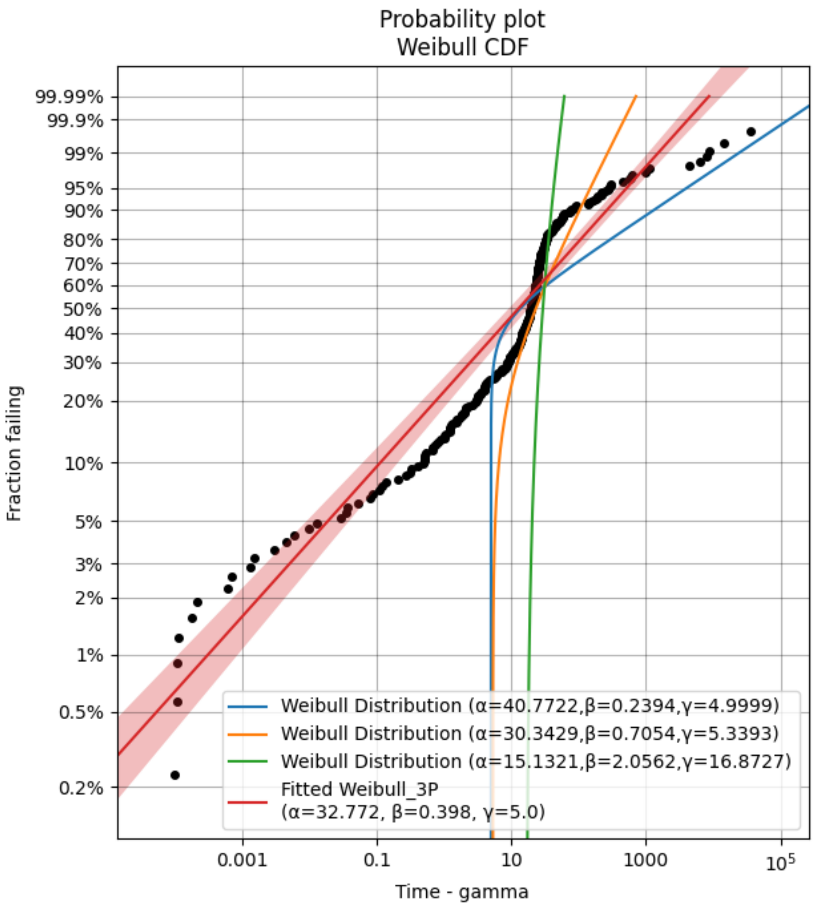
Beta: 2.05624

Gamma: 16.8727

- **We found the estimated optimal alpha, beta, and gamma values for the models developed in task4.**
- **Likelihood : $L(\theta \mid x) = f(x_1 \mid \theta) * f(x_2 \mid \theta) * \ldots * f(x_n \mid \theta)]$**

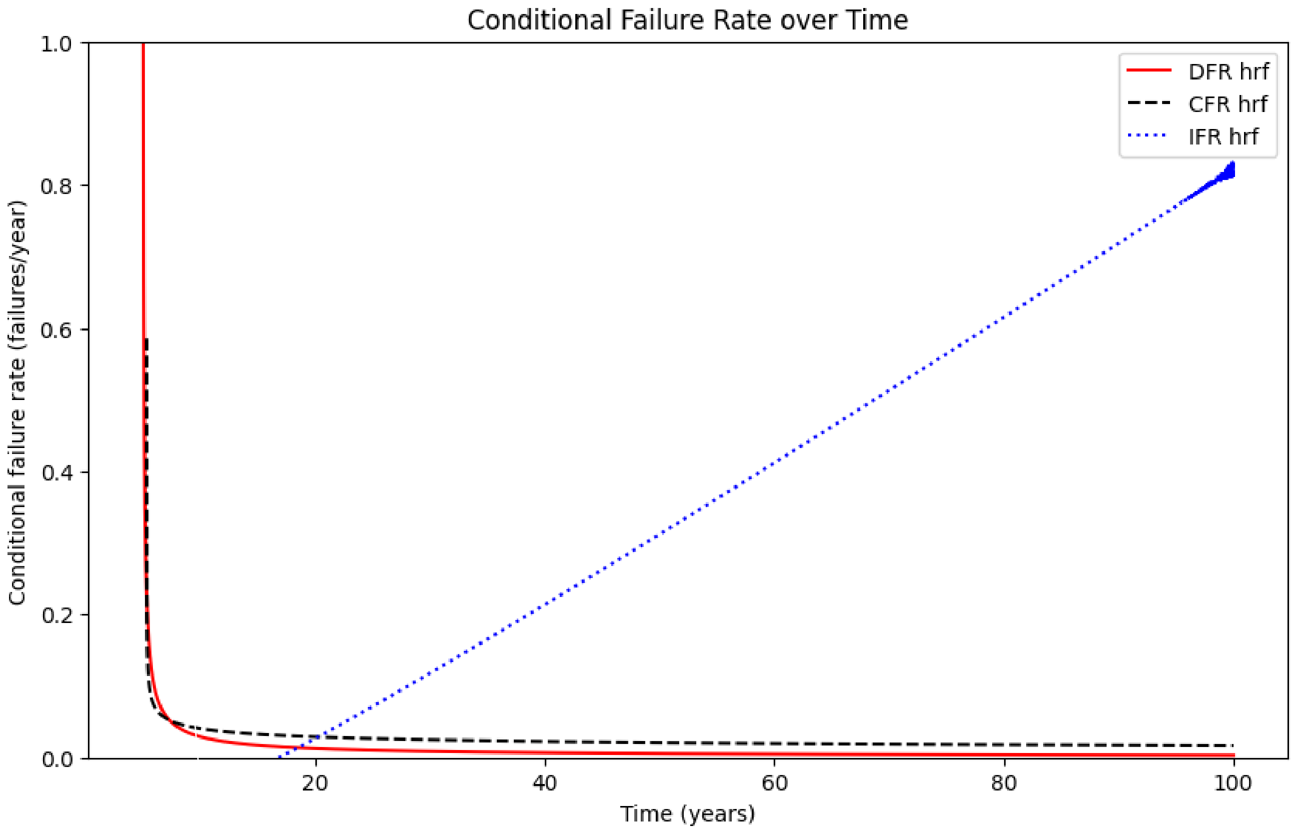
Task 6 : Analyze your results.





- This graph is a graph for the model estimated in each section and is the result of estimating as one model using this data.

Task 7 : Draw the estimated bath-tube curve.



- We can see the bath-tube curve of this electrical equipment system.

- The alpha, beta, and gamma values of each model following the data we generated have a large variance, so it was confirmed that the bath-tube cure was not well produced.