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RESEARCH ARTICLE

Analysis of Single Phase to Ground Faults Caused by Animals on Energy Not Served (ENS) in the Sumatera System

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Abstract

Animal disturbances on the High Voltage / Extra High Transmission Air Lines (SUTT / SUTET) in the work area of PT PLN (Persero) Sumatra Load Regulation and Distribution Center Main Unit (UIP3B Sumatra) during the period 2020-2024 have caused 208 animal disturbances on transmission lines and 35 animal disturbances on power transformers. This study provides information on mitigating animal interference, analyzing trends or patterns of animal habits that cause interference, and providing information on Energy Not Served (ENS). The data covers the period from 2020 to 2024, with a focus on evaluating the types of animals causing interference, the frequency and duration of outages, load data at the time of interference and the effectiveness of mitigation implemented, including recording the date, location, animal species, event classification, causal factors and response actions taken. This approach aims to improve understanding of the impact and behavior of wildlife on energy supply and to improve reliability and reduce the number of ENS. The results showed that the behavior of each animal was consistent with the fault data analysis, and the largest amount of undelivered power was monkeys 629.15 MWh, followed by birds 391.167 MWh and 358.04 MWh. Reducing the number of disturbances is done by preventive maintenance in animal-prone areas, with regular monitoring and evaluation so that ENS can be minimized.

Keywords: SUTT/SUTET, Energy Not Served, Animal Disturbance, Preventive

1. Introduction

PT PLN (Persero) is a state-owned electricity company that continues to commit and innovate in providing the best service for customers, especially in terms of providing electrical energy. PLN carries the Transformation 2.0 agenda with a vision

to become a Top 500 Global Company and become the number 1 choice for customers for Energy Solutions through business growth efforts, implementing end-to-end digitalization, carrying out energy transitions to support the achievement of Net Zero Emission (NZE), and presenting business processes with world-class human resources. In the Sustainable Development Goal (SDG's) program PT PLN (Persero) has goals or objectives listed in number 7, namely: Ensure the availability of affordable, reliable, sustainable and modern energy for all. Clean and affordable energy (affordable and clean energy).

Electric power today has become a basic necessity, ubiquitous and ever-increasing [1]. Almost all aspects involve technology and electricity to function, whether for households, offices, businesses, research, and for society [2] . Indonesia as a country with enormous biodiversity and a supporting population of 281.6 million people inevitably has to provide electricity in all regions [3]. One of the regions is Sumatra Island with an area of 473,481 km^2. As the geographical axis of wildlife distribution between mainland Asia and the Indonesian archipelago, Sumatra is considered a hotspot for new species discovery and home to a variety of wildlife species [4]. These two important issues, human and wildlife populations, seem to have collided with each other during this time. The rapid development of human settlements and amenities has transformed pristine wildlife refuges into human civilizations and is claimed to be the main cause of wildlife extinction [5].

This research aims to enhance understanding by providing knowledge about the causes of disturbances on electricity transmission lines caused by animal activity, including monkey, birds, and snakes. It seeks to offer information on effective mitigation and prevention strategies to reduce the risk of animal interference with transmission lines. Additionally, the study aims to explore animal behavioral patterns, focusing on the habits and behaviors of monkeys/mammals, birds, and snakes that may impact transmission line infrastructure. Furthermore, the research intends to assess the impact of animal interference on undelivered energy. To ensure a manageable scope, the study is limited to certain aspects: it focuses on specific animal types such as monkeys/mammals, birds, and snakes frequently causing interference; it is geographically confined to the mainland of Sumatra, excluding barren, dry, and snowy desert areas; the focus is on overhead transmission lines rather than underground ones, as they are more vulnerable to animal intrusion; and the scope centers solely on the impact on High Voltage and Extra High Voltage Transmission Line, excluding equipment in switchyards or substations.

Sumatra Island is one of the largest islands owned by Indonesia meaty in biodiversity. Sumatra with a total area of approximately 473,000 km^2, is the sixth largest island in the world and the second largest in Indonesia after Kalimantan, stretching approximately 1,700 km from north to south and 400 km from east to west . Sumatra is one of the world biodiversity hotspot due to its strategic geographical location, various topographical conditions, and complex geological history biodiversity hotspots with unique and rare endemic fauna. the relationship between the geographical location of Sumatra Island and its rich fauna based on recent studies. The discussion includes geological, biogeographical, ecological aspects, as well as conservation implications of Sumatran faunal diversity.

The causes of electrical faults can be both internal and external factors. Disturbances on transmission lines are often caused by natural factors such as lightning strikes, wind, trees, animals, and insulator contamination. While disturbances in the main equipment can be caused by insulation failure, mechanical damage, or misoperation.

About 40% of distribution network faults are caused by weather, 25% by equipment failure, 15% by vegetation, 10% by animals, and the rest by other causes including human error.

SUTT is a High Voltage Transmission Line with an operating voltage between 30 kV and 150 kV, while SUTET is an Extra High Transmission Line with an operating voltage above 150 kV up to 500 kV [6]. "Transmission lines can be classified as high voltage (HV) lines for voltages of 115- 230 kV, extra-high voltage (EHV) lines for voltages of 345-765 kV, and ultra-high voltage (UHV) lines for voltages above 765 kV.

Figure 1. High Voltage Transmission Line (SUTT)

The purpose of this research is to improve understanding, provide knowledge about the causes of disruptions in electric transmission lines caused by animal activities, including monkeys, birds, and snakes. Additionally, it aims to provide information on mitigation and prevention, identifying and communicating information regarding effective mitigation or prevention to reduce the risk of animalrelated disruptions to transmission lines. Furthermore, it seeks to provide information on animal lifestyle trends about the habits and lifestyles of animals, especially monkey, birds, and snakes, which may impact the transmission line infrastructure. It also aims to understand the impact of animal disruptions on unchannelled energy.

In addition to all of that, this research focuses more on the number of animal disturbances that cause outages, and how many ENS are not served due to those animal outages. Furthermore, there are several studies related to which months have the largest number of disturbances associated with the animals' habits. Additionally, it is important to identify which mitigation strategies are the most effective in addressing these animal disturbances. Finally, this research also calculates the technoeconomics of mitigating these animal disturbances, including how much capital is needed and what targets for ENS reduction can be achieved in the future.

2. Research Methods

2.1 Methodologi

This research was conducted with Field Observations to identify points prone to interference as wellas the behavior of animals that often interact with transmission lines. added with the calculation of Energy Not Served (ENS) by considering the duration of the outage and the load Served at that time, as well as innovations that have been implemented to mitigate the problem. The reactive mitigation approach involves identifying, recording and reporting events. This largely follows the standard operating procedures of PLN's scheme of work which are also equivalent to Southern Africa Energy Program/Endangered Wildlife Trust (SAEP/EWT). These include: Date of incident, Location of incident (GPS coordinates), Tower or substation number, Species involved, Classification of incident, Contributing factors (watercourses, farmland, wetlands, weather, etc.), Photos or videos to support the incident report. Statistical Analysis: To determine disturbance frequency patterns by animal type, location, and time of occurrence.

2.2 Time And Place Of Research

The research was conducted throughout the working area of PT PLN (Persero) UIP3B Sumatera, the reason for choosing this location is because of the geographical location and sufficient research resources to help complete this writing. Based on the geographical location of the island of Sumatra which has hills, mountains, extensive tropical rainforests. so it is very suitable for conducting research related to animals whose population and habitat are very large on the island of Sumatra, in contrast to the location on the island of Java which tends to be more stable and there are not many plains or hills like on the island of Sumatra. So it would be very appropriate to conduct research in areas that have high fauna diversity such as on the island of Sumatra. The research was conducted by taking data on disturbance events due to animals on transmission lines, both SUTT / SUTET, starting with disturbance data from 2020 to 2024.

3. Results and Discussion

3.1 Data Calculation of Number of Disturbances

This study aims to provide information on how much energy is not channeled due to disturbances caused by animals on the High Voltage Air Line (SUTT) / Extra High Voltage Air Line (SUTET) transmission line. Disturbance analysis is determined by the number of animal disturbances that occur on SUTT / SUTET, the following is the number of disturbances that occur during the period 2020 - 2024:

Table 1 above shows data due to animal disturbances that occur on the High Voltage Air Line (SUTT) / (SUTET) both temporary and permanent disturbances, temporary disturbances are momentary disturbances and without resulting in customers in the low voltage distribution system, while permanent disturbances are disturbances that are extinguished so that they cause outages to customers on the low voltage / distribution side. The longer the outage felt by customers due to animal disturbances in the SUTT / SUTET transmission line system, the greater the losses experienced by PT PLN (Persero). Animal interference does not only occur on the SUTT / SUTET

Table 1. Number of animal nuisances 2020-2024

Year	Total
2020	25 times
2021	38 times
2022	58 times
2023	67 times
2024	20 times

Transmission Line, but there are also disturbances caused by animals that occur in the Power Transformer and Incoming Power Transformer, but the number of times the disturbance that occurs on the SUTT / SUTET Line is more common in the system in Sumatra, the following is a table of the number of times the disturbance on SUTT / SUTET and Power Transformer / Incoming:

Table 2. Number of Animal Disturbances on feeder & Power Transformers

Year	Feeder	Transformer
2024	20	2
2023	67	7
2022	58	8
2021	38	10
2020	25	8
Total	208	35

The most animal-induced nuisances are caused by the following 3 animals: Monkeys,Birds,Snake In 2024, out of 25 conductor disturbances, 9 disturbances were caused by monkeys (36%), 8 disturbances were caused by birds (32%), and the rest were caused by snakes and weasels.

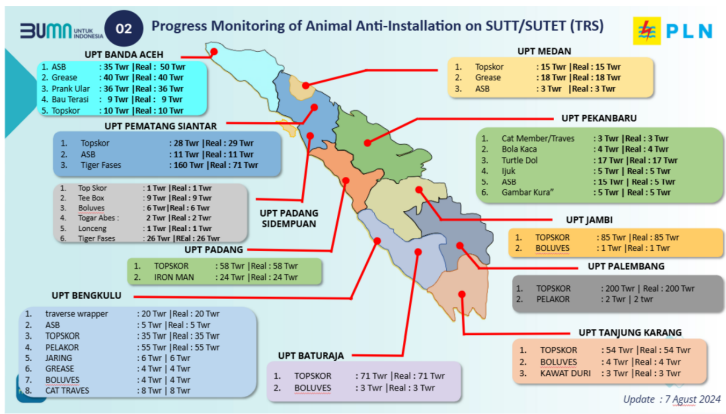

Figure 2. Progress of Anti-Beast Installation at UIP3B Sumatera

3.2 Mitigation of Animal Nuisance Prevention

Preventive measures are needed to prevent the occurrence of animal disturbances on SUTT / SUTET transmission lines, here is the mitigation information used to prevent the occurrence of these disturbances that have been realized at scattered locations in the Sumatra system. (Source : Report OF Verification Disturbance Monthly, 2024).

Various kinds of equipment or prevention methods owned by UIP3B Sumatera: ***Top Score*** (Isolator Protective Cap), is a wide disk (± 50 cm) equipped with a spiked top layer to prevent animals from touching the conductor. This tool is intended to protect or cover insulator plates from direct contact with animals such as snakes, birds, and primates. It is also effective for covering insulators from animal feces.

Figure 3. Top Score

Teebox Ball, is a striking glass ball with a chime sound to scare away animals especially birds from approaching transmission assets. Teebox balls are installed at a height and are intended top prevent birds from approaching facilities for gathering, roosting and nesting.

Figure 4. Teebox Ball

Iron Man, is a physical barrier made of sheet metal that makes it difficult for animals to access the tower. The sheet metal is approximately 3m high and has a slippery surface so that no part of it can be picked up by animals.

Figure 5. Iron Man on the Tower leg

Painting the tip of the traverses (cross arms), is the application of paint scents and bright colors intended to make animals, especially birds, feel uncomfortable and reluctant to nest in the tower.

Figure 6. Paint Traves

Pelakor (Arching and Conductor Protector) – Arching and conductor protector, is an Arc horn and conductor covered with insulating material so that if there are animals surrounding the object it does not cause a short circuit.

Figure 7. PELAKOR (Arching & Conductor Protector)

Turtle doll, is a turtle statue installed on a special tower to scare monkeys away from approaching the facility. The idea was adapted based on a legendary story originating from Bali. According to the myth, monkeys are afraid of turtles and try to use turtle dolls as an alternative to prevent monkeys and other primates from entering the tower.

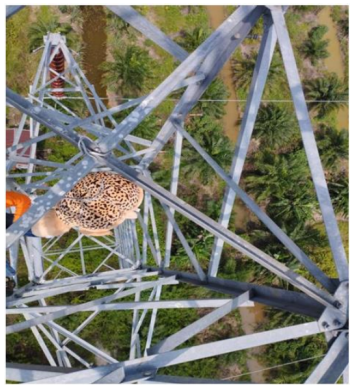

Figure 8. Turtle Doll

Tiger Feses, is one of the methods used in the work environment of PT PLN UIP3B Sumatra, especially in the working area of Sumatra Island. Tiger feces creates a very unpleasant aroma to scare away other animals like monkeys and several other mammal species. Tiger feses usually lasts only a few days or weeks depending on weather conditions; the smell produced at the transmission tower makes animals like monkeys reluctant to approach, thereby reducing the risk of disturbances caused by monkeys. Other research related to tiger feses has been conducted previously, but only on herbivorous animals such as goats and cattle.

Figure 9. Tiger Feses

3.3 Pattern of Monkey Disturbance

Table 3. Pattern Of Monkeys Distrubance

Cause	Years	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Monkey		12	10	5	6	9	7	14	12	6	9	11	15	116
	2020	1	3			1		1		1	1	1	4	13
	2021		1		1	2		2	3	4	4			17
	2022	2		3	2	3	3	5	4		2	2	4	30
	2023	2	3		2	1	3	2	3	1	1	5	5	28
	2024	5	2		1	1								9
Total		12	10	5	6	9	7	14	12	6	9	11	15	116

In Table 3 above it can be seen that in November - February there is an increase in the number of animal disturbances caused by monkeys and in March-August animal disturbances due to monkeys tend to be less. This is because during the rainy season monkeys and similar primates spend more time looking for food, Indonesia's rainy season is November - March .so that when monkeys and similar primates are looking for food they pass through the transmission channel because they feel the highest in order to see food sources. And in the dry season from March to August, macaques spend more time resting, so disturbance tends to be lower. Then for research related to monkey activity, [7].

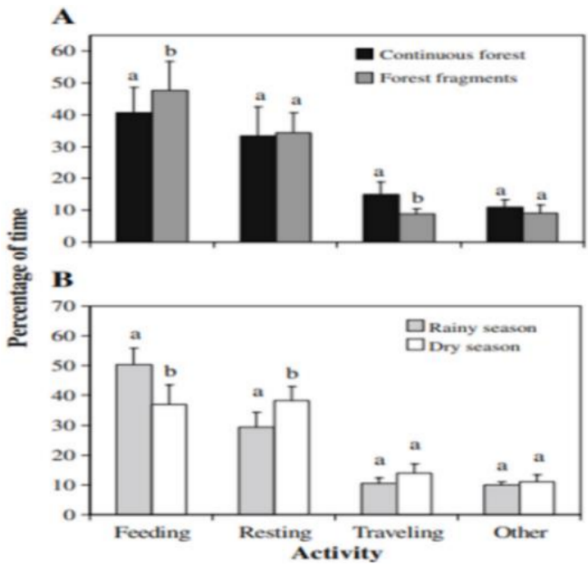

Figure 10. Pattern of Monkey in Dry & Rainy Season

Figure 10 shows that monkeys activity is usually more active during the rainy season where foraging is the most common time during the rainy season, where Indonesia and the location of the research have the same climate, namely tropical, in November - March is the peak of the increase in the number of disturbances caused by monkey.

3.4 Pattern Of Bird Disturbance

Table 4. Pattern of Bird Disturbance

Count of Cause	MONTH												
YEARS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEP	OCT	NOV	DEC	Total
2020				1	2		2					1	6
2022	1	1	2		3		3	1	1	4	1		17
2023	1	1	3	3	3	3	1	3	2	5	5		30
2024	2	1	4	1	1								9
Total	6	8	11	6	9	3	6	6	5	9	8	4	81

In Table 4 above, it can be seen that the trend of bird disturbances that occur shows that JanuaryMay is the breeding and egg-laying season for large birds (eagles). So that birds make nests to store their eggs, bird nests that stick to the transmission line, especially at the end of the Traves, will make the mother bird land close to the insulator and phase conductor so that if it sticks to the body or wing of the bird it will cause interference both temporarily and permanently, depending on the condition of the protection system that is working at that time. After that, in June-September, the eggs hatched, and the chicks were even able to fly off on their own to find food sources in nature, indicating that in June-September, bird disturbances decreased.

For Bird-related Research, [8] shows that the distribution of Javanese eagles in TNGGP is spread throughout the PTN Resort area. Estimated monitoring results of Javanese eagles are 43 individuals (2015), 49 individuals (2016), 44 individuals (2017), 33 individuals (2018), and 38 individuals (2019). From the results of monitoring for each year, the estimated results of monitoring Javanese eagles in TNGGP fluctuate. This is thought to be due to variations in seasonal and climatic patterns each year, such as the number of wet and dry months each year is not the same, and also due to other environmental factors that affect the presence of Javan eagles.

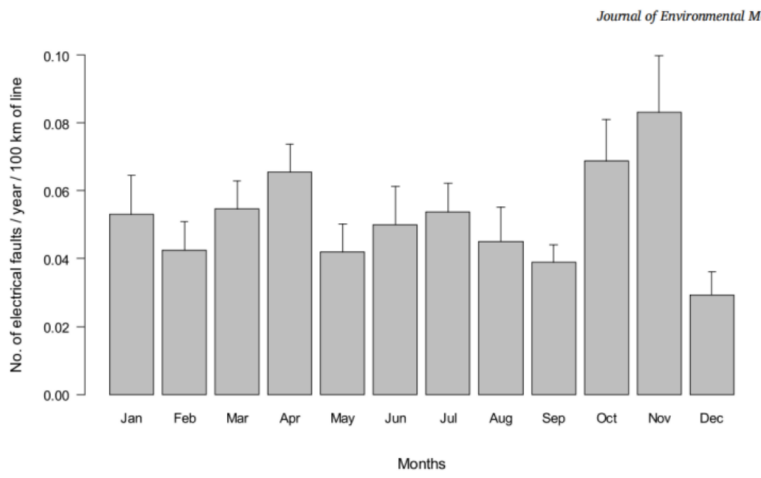

Figure 11. Research by Francisco Moreira

The Javan eagle breeding process usually takes place from January to May every year. It starts with the mating process in January, followed by nest building by the mother, egg laying, incubation, and hatching in April. After hatching, the young take up to two months to learn to fly. Until the age of 4-5 months, the mother continues to look after and feed it until the baby eagle can live independently.

This has been done by Francisco Moreira where his research is related to birds causing faults on transmission lines. Of the total 3367 electrical faults 25.3% were caused by birds, or 853 times. With the details of the most bird disturbances in April, October and November. With a trend pattern similar to the bird fault data conducted in this journal.

3.5 Pattern Of Snake/Reptile Distrubance

In early May to June is the most disturbance caused by snakes, this is because when entering the dry / hot season snakes begin to feel hungry after winter ends, so snakes become more aggressive in finding food sources such as bird eggs in transmission lines.

Table 5. . Patterns Of Snake Distrubance

Count of Cause	MTH										
YEAR	FEB	MAR	APR	MAY	JUN	AUG	SEP	OCT	NOV	DEC	Total
2020	1		1	1				1			4
2022	1			3	1	2	2		1		10
2023				2	1	1				3	7
2024			1	1							2
Total	**2**	**1**	**3**	**7**	**2**	**3**	**2**	**1**	**1**	**3**	**25**

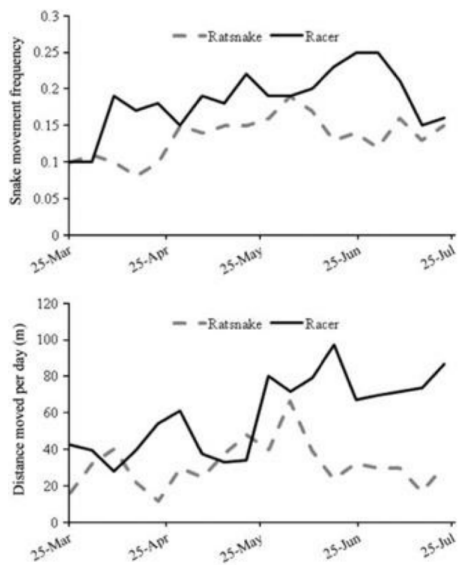

Figure 12. Distance moved per day for rat snake

In several studies related to snake activity namely, [9] with 463 bird variants (from 17 species), with 137 nests, where the results showed that in late May and early June was the peak of snake predators in preying on bird and rat nests. (more actively looking for food), starting from 2011-2013 with various types of bird nests studied. In accordance with the history of snake disturbance data.

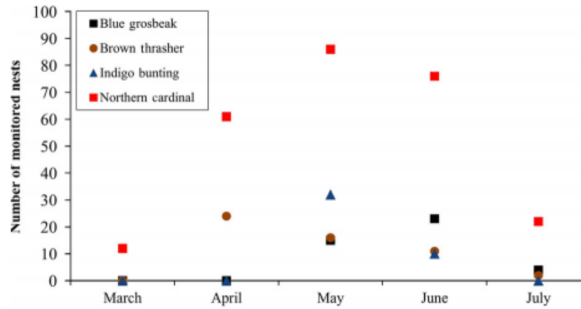

Figure 13. Bird droppings nest

Snakes hunt birds and rats, for birds the snake hunts up to the top of the tower to be able to get it, so that the movement of the snake is what causes interference with electricity transmission, where snakes perch on Traves or tower insulators and connect with phase cable conductors so that short circuit currents occur and cause both temporary and permanent interference.

3.6 Calculation of Energy Not Served (ENS) Due to Animal Disturbance on SUTT / SUTET Transmission Lines

ENS is a reliability metric that represents the amount of energy that the system does not deliver during a disturbance or power outage. It also includes the number of MWh lost due to outages, as seen in the following formula [10].

$$ENS = \Sigma \left[L(i) x Durasi(h) \right] \quad (1)$$

Description:
ENS : Undelivered Energy (MWh)
$\Sigma L(i)$: Total Active Power that Experiences Disturbance
Duration : Duration of Disturbance (Hours)

Table 6. Animal-Induced ENS in 2020-2024

Disorder	Year	ENS (MWh)
Animals	2023	404.14
	2022	448.63
	2021	316.38
	2020	274.58
Total		**1443.73**

In Table 6 above, it can be seen that every year there is a fluctuation in the number of ENS caused by animal disturbances; it cannot be confirmed whether next year there will be an increase or decrease that occurs due to animal disturbances. Further in determining or predicting the number of ENS that occur due to this Animal Disturbance. However, the efforts that need to be made to mitigate these things have actually been done, but there is a need for better disturbance prevention in the future. Because the mitigation of animal disturbances is also temporary, it is necessary to re-evaluate periodically if you want to get maximum results, especially in reducing the impact of customer outages and unchanneled ENS.

ENS calculation is obtained by determining the Rating Voltage when operating in the distribution system, for example, 150kV. Also looking for loads when a Trip disturbance occurs on that date, can be seen from the power transfer report.

This stage can produce the value of Power (Watt). Then after obtaining the Power, recalculate the Energy Not Served (ENS) by multiplying it by the duration of the disturbance (hour), and finally divide the result so that the unit becomes MWh.

The calculation of ENS in 2023 is based on the number of disruptions that experienced permanent outages with a certain duration, which are then calculated based on the power equation, and ENS is performed for each disruption that occurs throughout the year 2023.

Below is the calculation that has been carried out. Disruption on April 17, 2023, Segment Bukti Kemuning - Blumpu line 2. It is known that the highest load on that date was 571 Amperes. Operating at a voltage of 150 kV (150,000 V), Power 50.1 MW, duration 4.17 hours.

$$P = V \times 1 \times Cos \times \varphi \times \sqrt{3} \tag{2}$$

Where :

$$Cos\varphi = \frac{P}{V \times 1 \times \sqrt{3}} \tag{3}$$

Where :

$$Cos\ Phi = \frac{50.1\ MW}{150KV\ x\ 571\ A\ x\ \sqrt{3}} = 0.970$$

Cos Phi = 0.970 then :
P = 50.1 MW

$$ENS = \Sigma \left[L(i)\ x\ Durasi(h) \right] \tag{4}$$

ENS = 50.1 MW 4.17 hour = 208.917 MWh

Table 7. Conduit Load Data (SBU)

No	Feeder	Location	Load Report			
			Date	MW	I (A)	%THDI Nom
1	B.Kemuning – B. Umpu 1	T. 104	17/Apr/2023	50.1	571	45.68
2	B.Kemuning – B. Umpu 2		17/Apr/2023	50.1	571	45.68

Table 8. ENS Calculation for Animal Causes in 2023

Year 2023 (Animal Disturbance SUTT/SUTET) Trip							
V	P (MW)	P(Watt)	V.I	COS PHI	ENS (MWh)	I (A)	Duration (h)
150.000	50.1	50100000	51640500	0.970168763	208.917	571	4.17
150.000	50.1	50100000	51640500	0.970168763	65.13	571	1.3
150.000	16	16000000	17127000	0.934197466	4.32	66	0.27
70.000	19	19000000	20465900	0.928373538	23.75	169	1.25
150.000	60	60000000	66432000	0.903179191	13.2	256	0.22
150.000	128	128000000	138573000	0.923700865	23.04	534	0.18
150.000	92	92000000	100426500	0.916092864	34.96	387	0.38
150.000	42	42000000	43855500	0.957690598	24.36	169	0.58
150.000	7	7000000	7785000	0.899165061	1.19	30	0.17
150.000	24	24000000	46710000	0.513808606	5.28	180	0.22

Feeder	Voltage	Category	Cause	Date	Time		Durasi
					Off	Closed	
GI BUKIT KEMUNING BAY BLMPU # 2	150kV	ANIMALS	BIRD =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	17-Apr-23	7:08	11:18	4.17
GI BUKIT KEMUNING BAY BLMPU # 2	150kV	ANIMALS	BIRD =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	17-Apr-23	11:18	12:36	1.30
GIS OMBLN BAY 5A6 DIAMETER # 6 KLJAO #2	150kV	ANIMALS	SNAKE =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	14-May-23	20:30	20:51	0.27
GI TES BAY PHT 70 KV PHT PEKALONGAN 1	70kV	ANIMALS	SNAKE =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	30-May-23	20:03	23:00	1.25
GI SALAK BAY PHT 150kV SOLOK	150kV	ANIMALS	SNAKE =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	25-Jun-23	23:09	23:32	0.22
GI KYUNG BAY PHT 150 kV GMWNG # 1	150kV	ANIMALS	BIRD =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	16-Sep-23	7:11	8:20	0.18
GI PSDEM BAY PHT 150kV GNTUA	150kV	ANIMALS	MONKEY =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	15-Nov-23	13:25	13:48	0.38
GI TRTUG BAY PHT 150kV SBOGA #2	150kV	ANIMALS	SNAKE =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	1-Dec-23	2:57	3:32	0.58
GI NDLOK BAY PHT 150kV GLANG # 1	150kV	ANIMALS	MONKEY(UNCTR) => UNCONTROLABLE (SYSTEM FAULT)	24-Dec-23	9:10	18:56	0.17
GI KNTEN BAY PHT 150 kV TJAPI # 2	150kV	ANIMALS	MONKEY =>CONTROLABLE SISI TT/TM (SYSTEM FAULT)	30-Dec-23	15:22	17:41	0.22

The load data at the time of the disturbance was obtained from the 2023 report according to the location of the disturbance, namely at Bukit Kemuning - Blmpu 2 on April 17, 2023, amounting to 571 Amperes.

Table 9. ENS Calculation Table per year 2020-2023

Year	ENS Total	Monkey	Birds	Snake	Other
2023	404.14	41.43	297.08	65.63	0
2022	448.63	239.36	0	209.27	0
2021	316.38	177.66	94.08	44.64	0
2020	274.58	170.70	0	38.50	65.38
Total	**1,443.73**	**629.15**	**391.16**	**358.04**	**65.38**

From the table above, it can be seen that the largest total ENS is in 2022 with a total of 448.63 MWh, and the largest ENS contributor animal is the Monkey with a total of 629.15 MWh. The calculation, with the note that the disturbance taken into account is a disturbance that is a Final Trip / Trip that is actually extinguished (not a reclose disturbance). ENS per year is the sum of each cause of animal nuisance that occurs. there are 3 groups of animal nuisance that are calculated in determining the ENS above, namely: Monkeys, Snakes, Birds, and additional animals such as Ferrets or Bats.

Each type of disturbance is detailed in the calculation as follows:

Table 10. Animals causing ENS

Animal	Disturbance Times	ENS (MWh)
Monkey	11 times	629.15
Snake	7 times	358.04
Birds	6 times	391.16

with each animal having the number of disturbances as follows: monkeys 11 times, snakes 7 times, and birds 6 times

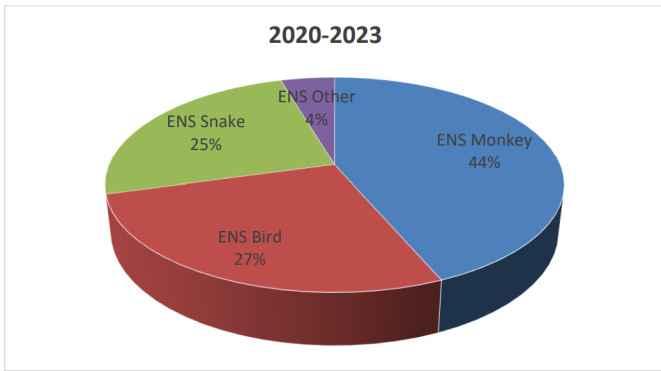

Figure 14. 2020-2023 Animal ENS Pie Chart

Of the three factors, the animal that causes the largest ENS is the Monkey where there are 11 disturbances with an ENS of 629.15 MWh, followed by animal disturbances of Birds and Snakes of 391.16 MWh and 358.046 MWh respectively.

Disturbances on SUTT / SUTET transmission lines based on causes are categorized into several main categories (Tools, Trees, Lightning, and those discussed above, namely Animals) while for other external causes of disturbances such as Generator Disturbances, Distribution Disturbances, APPL, and others cannot be discussed in the current study because they are external factors. The following is the ENS that occurs in the 2020-2023 period for several categories of internal causes of interference:

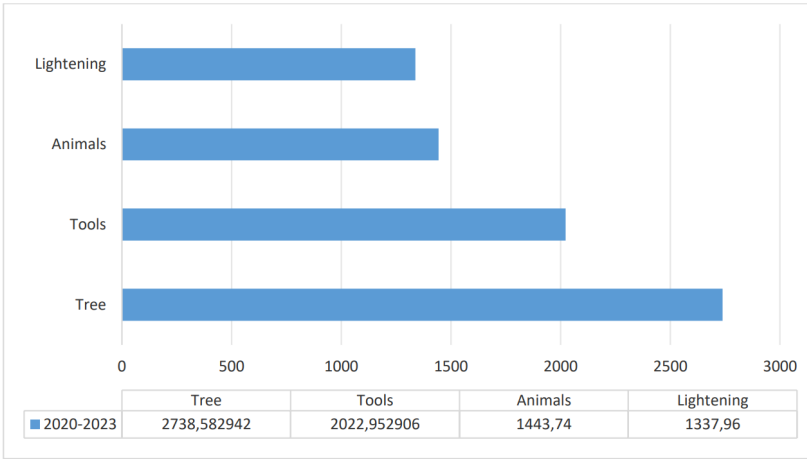

Figure 15. ENS Causes of internal interference year 2020-2023 (in MWh)

From the figure above, it can be concluded that the largest ENS impact of interference is due to Tree/Tree Interference of 2738 MWh (2020-2023). and interference caused by animals in 3rd position amounted to 1,443.75 MWh with the same period.

Based on other research, the mitigation tools to reduce ENS can vary, but the effective ones are TOP SKOR & Tiger Feses. These tools can prevent disturbances from animals such as birds, monkeys, and snakes that perch on insulators near conductors. These tools have been installed at several points in locations prone to animals, but not all towers have been equipped. The main objective is to prevent disturbances and reduce the outage rate that causes ENS. Here are the requirements for the installation of TOP SKOR and the impact related to the reduction of ENS, with a total ENS caused by animal disturbances amounting to 1443.73 MWh. If converted to rupiah with the current price of Kwh at Rp 1,444.70 per kWh, the lost rupiah value is:

ENS = 1443,73 x 1000 = 1.443.730 KWh
Rupiah per KWh = Rp 1.444,70
Loss = 1.443.730 x 1.443,7 = Rp. 2.084.356.312,00

Here we present the cost per unit for making TOP SKOR equipment and Tiger feses as tools used to mitigate animal disturbances and prevent the occurrence of ENS, as follows:

Table 11. Cost of TOP SKOR

No.	Title	Vol	Unit	Price (Rp)	Total (Rp)
1	**2**	**3**	**4**	**5**	**6 = 4 x 5**
A.	**TOP SKOR**				
	Material				
1	Plate Alumunium (d = 75 mm, T = 1,5 mm) Uk 1 mm x 120 x 240 cm	0,33	Set	772.502,50	257.500,83
2	galvanized nails sharpened	0,2	kg	38.634,75	7.726,95
3	Nail Rivet	20	pcs	673,35	12.567,97
4	Silver Galvanized Cat	0,01	kg	350.376,13	3.503,76
5	Mur dan Baut Diameter 10 mm, panjang 1,5 inchi	6	pcs	1.214,24	7.285,41
6	Aluminum Angle Plate	0,25	pcs	60.711,75	15.177,94
SUB TOTAL A					330.661,86
ROUNDING					330.662,00
B.	**Service**				
1	The cost of assembly and production of Top Skor	1	set	110.000,00	110.000,00
SUBTOTAL B					**110.000,00**
ROUNDING					**110.000,00**

For the ordering of this item (TOP SKOR), it takes about 1 to 2 months for production, depending on the quantity needed. Usually, the procurement process is carried out within the units only, taking into account the quality of the products.

Table 12. Cost of Tiger Fases

No.	Title	Vol	Unit	Price (Rp)	Total (Rp)
1	**2**	**4**	**3**	**5**	**6 = 4 x 5**
A.	**Tiger Fases**				
	MATERIAL				
1	Dus 300 mm x 120mm	1	Set	5.000,00	5.000,00

2	Feses Tiger	1	kg	35.000,00	105.000,00
SUB TOTAL A					**110.000,00**
ROUNDING					**110.000,00**
B.	**Service**				
1	Sending Material	1	Pck	110.000,00	110.000,00
SUB TOTAL B					110.000,00
SUB TOTAL A+B					220.000,00
ROUNDING					220.000,00

For this tiger fases, production is not always available. special orders are required from the nearest zoo. Usually, the zoo staff only provides it upon request, due to the limitations of tigers at that particular location. The shipping costs from the zoo to the unit location are adjusted according to the expedition shipping rates.

So, The budget required to create Top Skor is around **Rp 440,662.00** and Tiger Feses is around **Rp 220,000.00** by installing them massively at points vulnerable to animal disturbances, which can significantly reduce the ENS value due to disturbances by 1,443.75 MWh according to the research period, **or a reduction of 360 MWh**, **equivalent to Rp 521.089.078,22 per year.**

As a comparison material over the 4-year research period, there were 208 disturbances caused by animals on the transmission lines, with an average of 52 times per year, although not all resulted in outages. When compared to the number of outages that occurred over the same 4 years, there were 25 outages. The average per year was 6 outages due to animals, resulting in an ENS of 360 MWh per year. There is a need to increase the number of sets of mitigation equipment for animal disturbances in order to reduce the ENS outage rate. Therefore, a financial and operational feasibility study was conducted to determine whether this project is feasible or not, based on the cost per set for TOP SKOR equipment and Tiger Feses as shown in the table above. The target is to reduce the ENS by 360 MWh or 52 disturbances per year, with the requirement for each piece of equipment being:

- 52 sets of Top Score for each unit, 52 x 11 = 572 sets of Top Score
- 572 x Rp.440,662.00 = Rp 252,058,664.00
- 52 kg of tiger feses for each unit, 52 x 11 = 572 kg of tiger feses
- 572 x Rp.220,000.00 = Rp.128,000,840.00Total A + B = Rp. 380,059,500

Here are the results of the financial feasibility study that has been conducted:

By paying attention to the principle of caution in making investments and considering the implementation time, it can be seen that the evaluation results show that the project is feasible to run with an IRR of **49.23%** and a payback period of **1.35 years**. Then, to understand how effective each animal mitigation is, it can be seen in the table below:

Table 13. Feasiblity Study For TOP SKOR & Tiger Feses

Base Case			Unit
Voltage		150.00	KV
Maximum Power Capacity that is passed		52,000,000.00	KW
Energy Maximum is Passed		455,520,000,000.00	KWh per year
Growth ENS	6.0 %		
Losses	2.7 %		
Lifetime		2	Year
investment costs		380,059	thousand rupiah
Construction Start		2025	
Construction Period		1	year
Commision Year (Year 0)		2026	
Construction Disbursement			
Year 2025	50 %	190,030	thousand rupiah
Year 2026	50 %	190,030	thousand rupiah
Year 2027	0 %	-	
Year 2028	0 %	-	
Year 2029	0 %	-	
Cost			
Cost of Electricity Supply in Power Plants		-	
Variable Cost Pembangkit		644	Rp/KWh
Eskalasi Biaya Variable cost	0.00 %		
Cost O&M			
Biaya Fixed & Variable O&M		11,402	x1000 Rp/Year
Escalation Cost O&M	3.00 %		
General parameter			
Discount Rate	9.70 %		
Asumsi Nilai Tukar		15,000	Rp/USD
ppH	22 %		
Benefit		-	
A. Sales Addition			
Delta ENS		360,000	KWh
Sell Cost		1,534	Rp/KWh
B. Revenue Beyond kWh			
Revenue Beyond kWh			
C. Savings			
Savings Losses Teknis		-	KWh

Saving Others		-	x 1000 Rp/Year
	Total Saving	-	x 1000 Rp/Year
RESULT			**Kriteria**
IRR	**49.23 %**		>Discount Rate
NPV	**132,791**	x1000 Rp	>0 (positif)
B/C Ratio	**1.15**		>1 x
Payback Period	**1.35**	Year	<10 Year
.....		.....	

Table 14. Evaluation Of Mitigation Disturbance Animals

No	Feeder	Caused	Mitigation (Installed)	2024	2023	2022	2021	2020	2019	Result
1	DURI – BBATU	Bird	ASB (2022), Turtle Doll (2021)		x	x	x			Not Effective
2	SKMRD-PKLGN	Monkey	Grace (2019), Ijuk (2020)					x	x	Not Effective
3	GRDSK – BNKNG	Bird	Boluvest (2019)						x	Effective
4	BTUNG –SGLIN	Monkey	Top Skor (2023)		x					Effective
5	SALAK-SOLOK	Snake	Iron Man (2023)		x					Effective
6	PPGRN-BNKNG	Monkey	Tiger Feses (2023)		x					Effective

Noted :
x = interference

From the table above, it can be seen that after the installation of Top Skor on the BTUNG-SGLIN segment, disturbances from monkeys no longer occurred, while in the DURI-BBATU segment, disturbances reappeared in 2022 and 2023 after being absent in 2021. Similarly, for Tiger Feses, it is considered effective because after the installation on the PPGRN – BNKNG segment in 2023, there have been no more disturbances until 2024.

4. CONCLUSION

Based on the discussion of the results, the analysis can be concluded as follows, The calculation of undelivered energy / ENS that occurs due to animal interference during the observation period carried out, namely 2020-2023 on the SUTT / SUTET transmission line in the working area of PT PLN (Persero) UIP3B Sumatra is influenced by the number of times a disturbance occurs that causes customer outages / Trips where the reference number of customer loads at that time is the active load available then goes out due to animal interference, and the duration of outages/trips that occur due to animals. Where the animals are divided into 3 main groups, namely birds, monkeys, and snakes. The factors causing animal interference follow the pat-

tern of life habits of each animal, by looking at the results of research related to the time of the animal breeding, foraging, and interacting, that has been done by research from other sources. Of the three factors, the animal that causes the largest ENS is the monkey, where there are 11 disturbances with ENS of 629.15 MWh, followed by animal disturbances of birds and snakes of 391.16 MWh and 358.04 MWh, respectively. In general, animal disturbance is the 3rd largest cause of ENS, where the largest ENS is caused by stands/trees, amounting to 2738 MWh. And after that, the disturbance is caused by the Tools amounting to 2022 MWh.

In terms of reducing the number of animal disturbances, it can be done with more massive preventive maintenance throughout the transmission line, especially in areas prone to animal disturbances, more routine checks/inspections and system improvements in handling network outages need to be prepared to ensure the reliability of electricity supply so that there are no customer outages that cause ENS to rise. In anticipation of the largest ENS disturbance, namely disturbance due to stands/trees, it is necessary to have a more targeted tree felling work program in accordance with applicable standards, namely ESDM Ministerial Regulation Number 13 of 2021 concerning the closest distance from trees to conductors when they fall is 5 meters [11]. In addition to minimizing ENS interference due to trees/stumps, this is also a solution in dealing with animal interference caused by monkeys, birds, or snakes that have been discussed in this research.

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