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Results From Changes in The Pole of 15 kV Power Transmission Lines

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Abstract — Baganuur Southeast Electricity Distribution Network 15kV electrical transmission line interruptions research was conducted, and a factor analysis was performed to determine the conditions of the line outage. Due to the neutral grounding of the 15kV electrical transmission line and the relatively small distance between the line wires and crossbar, there is a high incidence of grounding during the landing and flight of birds, which hurts the reliable operation and ecology of the line. Therefore, the structure of the poles changed, and the results were reflected.

Keywords—electrical transmission lines; interruption; structure of pole; design; factor

I. INTRODUCTION

In connection with the transition from a nomadic civilization to an urban civilization, the electrification of urban and rural areas and their access to centralized electricity are included in the Government's plan of action every year and financed from the State budget. To accomplish this work, a new intermediate voltage standard was introduced as a new technique and technology for the long-range transmission of electricity with high quality and investment savings. Currently, 0.4, 6, 10, 15, 20.2, 22, 35 kV voltage levels are used in the distribution network.

Before early 2000, 6, 10 and 35 kV isolated neutral transmission lines were built in rural areas. It is impossible to pass a distance of more than 40 km on a 10 kV electro-transmission line/ETL/. However, the distance between settlements is usually more than 60 km. As a result, it is insufficient to choose a 10 kV voltage. Most places were required to associate with an electrical transmission line of 35 kV. However, the maximum capacity that can be transferred on the 35 kV line is many times higher than the needs of the settlements, making it a resource that will never be used.

Thus, in 2003, consumers of the Delgerkhangai (Dundgobi province) sum were electrified for the first time by a line of 15kV with 58.8 km. Currently, 4,279 km of 15kV transmission lines and 268 substations are operating in Mongolia [1].

II. FEATURES AND NEUTRAL MODE OF 15KV TRANSMISSION LINE

All distribution networks in our country work in an isolated neutral mode, and in the event of a phase ground during such a mode, it is allowed to operate with grounding for 2 hours by the Electrical Installation Rules (EDC) in force country. That area will be a danger zone for 2 hours until to found the damaged part [3, 5]. When a person or animal (living entity) enters this area, it is exposed to voltage. The 15kV network used in the distribution network is operated in a deep grounded neutral mode to avoid this situation. A short-circuit current flows through the ground point when a single phase is grounded in a deep-grounded neutral mode. This short-circuit current allows the relay protection to operate and disconnect the line without a time delay in the event of a ground fault. This is a positive aspect of the 15kV transmission line with deep-grounded neutral mode, but there are some difficulties during operation. Therefore, it is necessary to conduct a study of 15kV electrical transmission line interruptions to theoretically determine the factors influencing the interruption and identify ways to reduce the impact of these factors. The following problems occur during the operation of a 15kV deep-grounded neutral overhead transmission line. These include:

1. From the design of the pole, it is not possible to make a wire vibration damper due to the vertical position of the insulating element holding the conductor wire, and there are many cases when the phase conductor wire breaks.
2. The poles are located at a height suitable for nesting and migratory birds, remote observation of their prey, hunting from a height, and repairing their nests for birds, which creates conditions for migratory and birds of prey to be exposed to voltage.
3. Due to the above two conditions, the number of power interruptions increases, and the conditions for uninterrupted power supply to consumers are decreasing.

Therefore, to reduce the number of faults, it is advisable to change the design of the 15kV electrical transmission line poles.

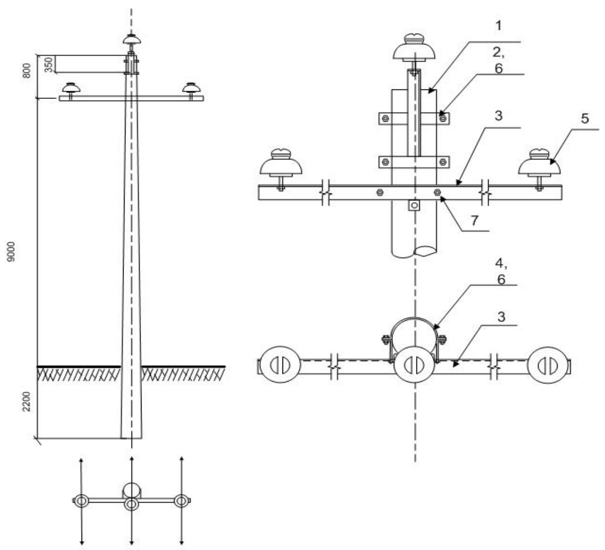

Figure 1. Structural design of the pole

Table 1. Datasheet of pole

№	Structure name	Shape	Amounts	Φ 190/350 pole		Φ 300/300 pole		Explanations
				Unit weight [kg]	Pole's weight [kg]	Unit weight [kg]	Pole's weight [kg]	
1	Pole	12 м	1					
2	Head	L63x6x175 _63x6x400/660	1	6,83	6,83	10,0	10,0	B2.405.2.01 - 2000 D1
3	Crossbar	L75x6x1700	1	11,71	11,71	11,71	11,71	B2.405.2.01 - 1000 D1
4	Crossbar fasteners	Φ16/660	1	1,04	1,04	1,33	1,33	B2.405.2.01 - 1200 D1
5	Insulator	P-15T	3	3,3	9,9	3,3	9,9	
6	Screw-bolt	M16x7, M16	4	0,1	0,4	0,1	0,4	
7	Screw-bolt	M16	4	0,05	0,2	0,05	0,2	
	Structure of iron construction							

III. Research on interruption of electrical transmission line

The statistics on breakdowns for 14 of 15kV transmission lines under the responsibility of "BSEDN" SOEC were reviewed as of 2015-2019.

The total number of faults between 2015 and 2019 is shown separately.

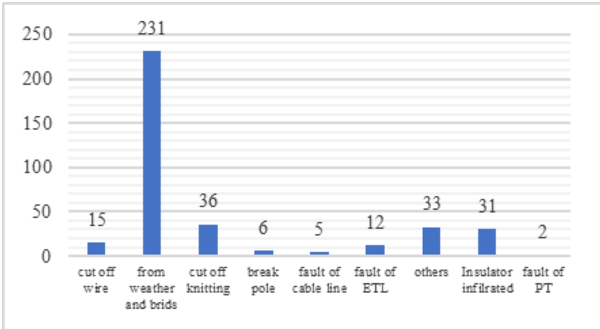

Figure 2. Reasons for breakdowns in 2015-2019

The calculation data of the main equipment and machines used for calculating the energy system mode are entered according to the required data of the "Powerfactory" calculation program. Generators, block transformers, power transformers, circuit breakers, switches and loads, cable lines, and short-circuit current limiting reactors are designed [5-11].

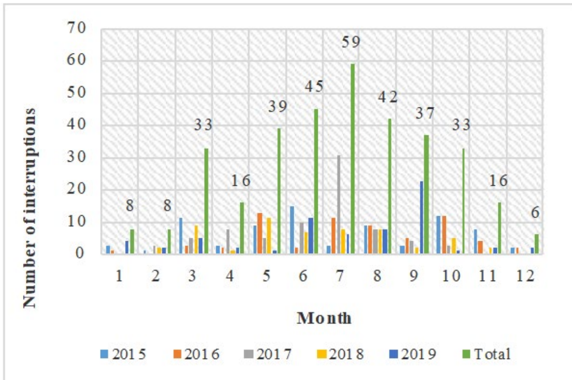

Figure 3. The 15kV electrical transmission line faults to show from 2015 to 2019 by months

The total length of the line is 878.07 km, and the number of interruptions was 371. The average annual interruption per 100 km of 15kV electrical transmission line of “BSEDN” is 8.4, which is 1-1.6 times higher than the statistical data and standardized norm of similar lines in other countries.

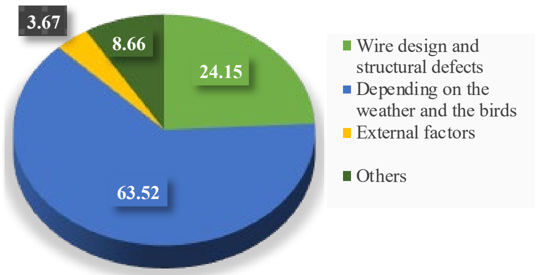

Figure 4. Reason for the fault of 15kV electrical transmission line

24.15% of interruptions are due to structural defects of the wire. This is due to the fact that the contractors do the installation work in a short period of time with minimum quality. Significant interruptions due to equipment fault, such as fault to the overvoltage limiter and automatic reclosing protection block, are accountable for a substantial percentage. This is due to the installation of equipment that is not suitable for the climatic conditions of our country.

IV. Factor Analysis

One of the main methods of statistics and econometrics is the linear regression method. This method analyses the factors affecting 15kV electrical transmission line fault.

Three main factors that affect the 15kV electrical transmission line interruption were selected and calculated using E-views software.

Analysis of factors influencing 15kV electrical transmission line faults

Table 2. Calculation results

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	26.42889	0.331871	79.63610	0
X1	0.850813	0.011224	75.80313	0
X2	0.635206	0.006237	101.8475	0
X3	1.204343	0.043666	27.58048	0
R-squared	0.999553	Mean dependent var		76.20000
Adjusted R-squared	0.999469	S.D. Dependent var		6.970615
S.E. of regression	0.160569	Akaike info criterion		-0.643333
Sum squared resid.	0.412517	Schwarz criterion		-0.444186
Log-likelihood	10.43333	Hannan-Quinn		-0.604457
F-statistic	11930.49	Dubin-Watson Stat		0.780250
Prob. (F-statistic)	0			

The mathematical model of regression is:

$$Y = 26.4 + 0.85X1 + 0.63X2 + 1.2X3$$

Table 3. Formulas and explanations[6, 7]

Name	Formulas and explanations
Coefficient of determination	$R^2 = 1 - \frac{\sum_{i=1}^{n} e_i^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$
Adjusted determination coefficient	$\bar{R}^2 = 1 - \frac{\frac{1}{n-k}\sum_{i=1}^{n} e_i^2}{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2}$
S.E. of regression	$\sigma = \sqrt{\frac{\sum_{i=1}^{n} e_i^2}{n-k}}$
Residual sum of squares	$RSS = \sum_{i=1}^{n} e_i^2$
Log-probability	$LogL = -\frac{n}{2}log2\pi - \frac{n}{2}log\sigma^2 - \frac{\sum_{i=1}^{n}(y_i - \beta_1 - \beta_2 x_i)^2}{2\sigma^2}$
F-statistics	$F = \frac{(RSS_r - RSS_u)/(k-1)}{RSS_u/(n-k)}$
Dependent on the average of the variables	$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$
Dependent on the standard deviation of the variable	$S.D = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}}$
Akaike information criterion	$AIC = log\left(\frac{RSS}{n}\right) + 2k/n$
Schwarz criterion	$SIC = log\left(\frac{RSS}{n}\right) + (k\ logn)/n$
H-Q (Hannan-Quinn) criterion	$HQ = log\left(\frac{RSS}{n}\right) + 2k\ log(logn)/n$
Dubin-Watson statistics	$DW = \frac{\sum_{t=1}^{n}(\hat{e}_t - \hat{e}_{t-1})^2}{\sum_{t=1}^{n} \hat{e}_t^2}$

The determinant coefficient is denoted by econometrics as R^2, and indicates what percentage of the actual value of the estimated regression equation explains the value. $0 \leq R^2 \leq 1$, and the closer to 0 the equation evaluated indicates that the ability to interpret the actual value is insufficient, and the closer to 1, the better the interpretation of the actual value. The following factors were selected and calculated:

- Wire design and structural defects
- Depending on the weather and the birds
- External factors
- Others.

The results of the calculations show that the above three selected factors (wire design and structural defects (X1), depending on the weather and the birds (X2), and external factors (X3)) have a 96.33% effect on line breakage.

To determine the coefficients of determination of the three influencing factors separately:

- Wire design and structural defects -0.64
- Depending on the weather and the birds -0.80
- External factors -0.13

These estimates show that a very high percentage of weather and bird damage is involved in electrical interruption on 15kV transmission lines.

Therefore, to reduce the number of faults, it was decided to change the pole structure in the 15kV electrical transmission line. According to the new model (Figure 5), 86 km of Adaatsag 15kV electrical transmission line, powered by 35/6 kV Tevshiin Gobi substation of Dundgovi province, is being used.

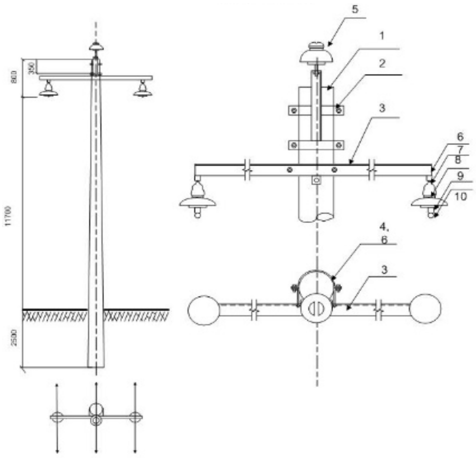

Figure 5. Structure of pendulum insulation

Table 4. Datasheet of pole

№	Structure name	Shape	Amounts	Ф 190/350 pole	
				Unit weight [kg]	Pole's weight [kg]
1	Pole	15 м	1		
2	Head	L63x6x175 63x6x400/660	1	6,83	6,83
3	Crossbar	L75x6x1700	1	11,71	11,71
4	Crossbar fasteners	Ф16/660	1	1,04	1,04
5	Insulator	P-15T	3	3,3	9,9
6	Clamp	Z-7	4	0,1	0,4
7	Earring	Q-7	4	0,05	0,2
8	Insulator	ПС-70	2	3,5	7
9	One-line headphones	W-7	2	0,4	0,5
10	Detachable clamp	У 1-7-16	2	0,4	0,4

The pole structure in the 86 km Adaatsag 15kV electrical transmission line powered by the 35/6kV Tevshiin Gobi substation in Dundgovi province has been redesigned with a swing-insulated model (Figure 5), compared parameter data of new and old designs shown at Table 4. When the transmission line was changed, 12 fresh and apparently dead birds along the route were removed, and a total of 51 birds were found under the pillars, 12 of which were falcons [8].

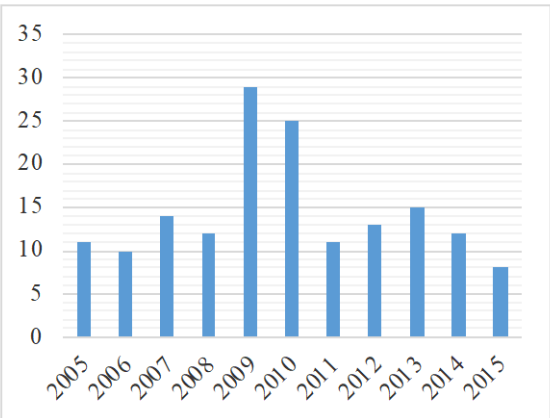

Figure 6. Number of interruptions of Adaatsag 15kV electrical transmission line in 2005-2015

The 15kV electrical transmission line was cut off an average of 16 times a year, at least eight times and at most 29 times, with an average of 30-51 birds per year, of which 8-12 falcons die of affected by voltage [1, 2, 4].

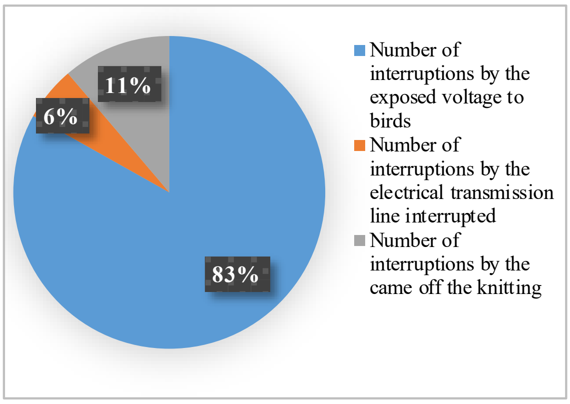

Figure 7. Classification 15kV electrical transmission line interruptions

- Between October 2015 and October 4, 2016, a total of 13 interruptions occurred, dying 18 birds.
- Between September 4 and 9, 2016, the Adaatsag 15kV electrical transmission line was overhauled. During the inspection, in TN№ 70, 112, 135, 150, 160, 170, 180, 212, 215, 210, 241, 250, 280, 290, a total of 18 birds were exposed to the voltage of which 4 were falcons, 4 were white elegt (a species of bird of prey) and 10 were crows.
- During the examination on February 16-17, 2017, 1 crow and 2 white elegts (a species of bird of prey) died on TN№175, 195 and 204 poles.
- These birds were usually affected by the voltage between the first phase in a pole of the anchor and the top of the pole.

The new structure of the 15kV electrical transmission line pole will almost double the cost of insulation (approximately MNT 1-1.2 million per 1 km line), and there is a risk of insulation leakage, phase conductor breakage, and migratory and predatory birds are line voltage decreased by 60-70%.

In other words, 7-8 million MNT (2200-2500 USD) spent on fault destruction will be reduced by 30-40%, and the exposure of rare birds to voltage will be reduced, which will positively impact the environment.

CONCLUSIONS

Electrical transmission lines account for about 80 per cent of all power system equipment failures. Because the electrical transmission line is located in the open air, it is vulnerable to various climatic phenomena and changes. In addition to weather-related damage, the damage is also caused by installation errors and external influences.

In addition, the distance between the poles of the 15kV transmission line is 80-120 m, and according to the survey, 13.75% of the total outages are due to wire breakage and wire harness failure. Therefore, installing a vibration damper or soothing loop in the 15kV electrical transmission line is necessary.

The factor analysis results show that the coefficient of determination of weather and bird-related faults is 0.80 or much, which indicates the need to change the design of the pole. The easiest way to overcome these problems during a 15kV electrical transmission line is to fully implement the new pole design. This is fully confirmed by the operation of the Adaatsag 15kV electrical transmission line.

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