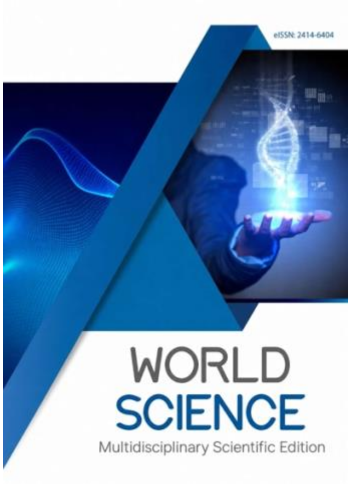

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OUTAGE ANALYSIS AND EFFICIENCY IMPROVEMENT OF A 110 KV OVERHEAD TRANSMISSION LINE IN DALANZADGAD, MONGOLIA

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ABSTRACT

This paper presents an analysis of outage characteristics and efficiency improvement measures for the 110 kV Dalanzadgad overhead transmission line in Mongolia using operational data from 2016 to 2024. The study examines the influence of key environmental and technical factors such as insulator contamination, weather conditions, conductor defects, and bird-related incidents. During the study period, 46 outage events were recorded, of which 45.6% were associated with bird activity, 36.9% with insulator contamination, and 17.5% with weather conditions. These results show that environmental factors play a dominant role in the occurrence of outages. The effectiveness of maintenance measures was also evaluated. The number of locations affected by compression splice sleeves and protective coatings was reduced, which improved conductor surface conditions and resulted in an estimated reduction in line losses of approximately 11%. In addition, the replacement of conventional insulators with aerodynamic-type insulators significantly reduced contamination-related outages by 88%. The results suggest that appropriate maintenance strategies and targeted mitigation measures can improve the operational reliability and efficiency of overhead transmission lines, particularly under harsh environmental conditions.

KEYWORDS

Bird, Splice Sleeve, Protective Coating, Insulator Contamination, Electric Arc

CITATION

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Introduction

Over the past decade, socio-economic development in Mongolia has accelerated, accompanied by the rapid expansion of the mining, manufacturing, construction, and infrastructure sectors. Correspondingly, total electricity consumption has been increasing year by year; in particular, the intensified exploitation of major mining deposits in the southern region has led to a significant rise in the loading of the transmission network. (Energy Regulatory Commission of Mongolia, 2023; National Dispatching Center of Mongolia, 2022). Factors such as population growth, urbanization, technological advancement, automation, and digital transformation are further accelerating the increase in electricity demand, thereby necessitating that the reliability and stability of the power system be addressed at a strategic level.

The reliable operation of the power system is a fundamental prerequisite for sustainable socio-economic development, and it is directly associated with the continuity of electricity supply, power quality indicators, and the flexibility of the system. (Billinton & Allan, 1996). One of the key factors affecting system reliability is the technical operation of overhead transmission lines (OTLs), the condition of their equipment, and the impacts of environmental factors (Gönen, 2014; Gonen, 2008). In particular, contamination of high-voltage line insulators increases the risk of elevated surface leakage currents, arc formation, and unexpected outages, and is directly correlated with the degree of contamination, humidity, wind speed, and dust concentration levels (International Electrotechnical Commission, 2008; Farzaneh, 2008). The 110 kV Dalanzadgad overhead transmission line, which is of strategic importance to the power supply of the southern region, serves as a primary source of electricity for Dalanzadgad city and its surrounding mining areas. The line was commissioned in 2013 and has a total length of 86.9 km, comprising 13 anchor towers and 333 suspension towers. In recent years, a significant increase in the movement of heavy-duty coal transport vehicles along the route has intensified ambient dust levels, thereby creating conditions conducive to the accumulation of contaminants on the surfaces of line insulators. This effect is further exacerbated by the dry and windy climatic characteristics of the Gobi region, leading to a reduction in the dielectric strength of insulator surfaces and an increased risk of unplanned outages and interphase arc formation.

Failures caused by insulator contamination not only reduce the operational reliability of transmission lines but also adversely affect the stability of the power system, thereby posing risks to the continuity of electricity supply to consumers. Therefore, investigating the level of insulator contamination on the 110 kV Dalanzadgad overhead transmission line, its impact on dielectric strength, and its statistical relationship with outage events is of significant scientific and practical importance, as it enables the optimization of maintenance regimes, cleaning intervals, and appropriate protective measures. The objective of this study is to determine the relationship between the level of insulator contamination on the 110 kV Dalanzadgad overhead transmission line and its operational reliability, and to develop and propose measures to enhance the efficiency of technical operation.

Research materials and methodology

The route of the 110 kV Dalanzadgad overhead transmission line (OHL) is aligned in an east–west direction and is continuously exposed to the prevailing wind flow of the Gobi region, which predominantly blows from the northwest to the southeast. Due to the regional climatic characteristics, winds with an average speed of 7–8 m/s prevail throughout all four seasons. In recent years (since 2018), according to data reported by the Umnugovi Province Hydrometeorological and Environmental Monitoring Agency, the number of days with strong winds of 15–20 m/s has increased from 4 to 22 days, indicating a significant rise in both wind intensity and frequency. These strong wind events are predominantly observed during the spring season and are characterized by their prolonged duration.

The wind load acting on overhead line conductors varies in direct proportion to the square of the wind speed. Consequently, when the wind speed doubles, the load exerted on the conductors increases by a factor of four.

This wind action induces low-amplitude, high-frequency vibrations in the conductors, which can lead to strand separation near the supports, resulting in compression splice sleeve and an increased incidence of conductor damage and breakage. A survey conducted in 2016 along the entire length of the 110 kV Dalanzadgad OHL identified compression splice sleeve at 125 locations and protective coating at 44 locations.

At locations along overhead transmission lines where compression splice sleeve and protective coating occur, the surface resistance decreases, allowing small leakage currents to flow along the surface. These currents result in continuous losses, thereby increasing electrical energy losses. Furthermore, they intensify corona activity and heat generation in the conductors, which accelerates aging and reduces the service life of the overhead line conductors (CIGRE Working Group C4.303, 2013; Wang & Sun, 2016).

In sections subjected to mechanical compression and binding, the effective cross-sectional area of the conductor decreases, inter-strand contact resistance increases, and surface roughness is enhanced, leading to a rise in both surface and contact resistance. Such changes result in increased localized heating, which elevates the conductor temperature and consequently increases line losses (Grainger & Stevenson, 1994; Kuffel et al., 2000). The rise in temperature also leads to increased sag and altered mechanical loading conditions, thereby adversely affecting the operational reliability of the transmission line (IEEE Power & Energy Society, n.d.; IEEE Power & Energy Society, 2019).

In practice, an empirical estimate is often cited whereby a single compression splice sleeve contributes approximately 1% and a single protective coating approximately 1.5% to transmission losses; however, these values vary significantly depending on line voltage, current, conductor type, surface condition, and prevailing climatic conditions.

As shown in Table 1, the study results indicate that migratory birds and insulator contamination have a more pronounced impact on outage occurrences along this overhead transmission line.

Outages resulting from system isolation by automatic protection schemes were not included in this study.

Table 1. Study on the Causes of Outages in Overhead Transmission Lines

№	Line name	Causes of Outages	2016	2017	2018	2019
1	110 kV Dalanzadgad Overhead Transmission Line (OHL)	Due to bird-related causes	2	2	1	4
2		Due to element burn damage and contamination	2	4	2	3
3		Due to weather conditions	1			
4		Total	5	6	3	7

As shown in the table above, the structural analysis of outage causes indicates that 37.5% of the total outages were attributable to the intrusion of migratory birds into the line, while 30.4% were caused by insulator contamination. The remaining proportion is associated with various technical and other environmental factors; however, these two primary causes together account for 67.9% of all outages, demonstrating their dominant influence on the operational reliability of the transmission line.

The outage performance of this overhead line is significantly affected by regional characteristics of the Gobi area, including the seasonal migration of birds, high levels of dust, a dry and windy climate, and the proximity of coal transportation routes to the line corridor.

Results of the research

The study identified that conductor strand breakage, protective coating, leakage caused by insulator contamination, and bird-related incidents constitute major factors increasing outage frequency and posing tangible risks to the operational reliability of overhead transmission lines. Accordingly, major maintenance works were undertaken to reduce outage occurrences, mitigate technical failure risks, and ensure uninterrupted power supply to consumers.

As a result of the maintenance activities, the number of locations with compression splice sleeve along the line corridor was reduced to 51, representing a decrease of 74 points (59.2%), while the number of locations with protective coating was reduced to 29, a decrease of 15 points (34.1%). The reduction in compression splice sleeve and protective coating improved the surface uniformity of the conductors, decreased localized contact heating points, and led to an approximate 11% reduction in line losses.

To mitigate outages caused by insulator contamination, the lower insulators of phases 1, 2, and 3 on all suspension towers along the entire line were replaced with aerodynamic-type insulators in 2019 and 2022. The analysis of overhead line outages from 2020 onward is presented in Table 2.

Table 2. Post-Maintenance Analysis of Overhead Transmission Line Outages

№	Line name	Causes of Outages	2020	2021	2022	2023	2024
1	110 kV Dalanzadgad Overhead Transmission Line (OHL)	Due to bird-related causes	2	2		4	4
2		Due to element burn damage and contamination		2	2	2	
3		Due to weather conditions		2		2	3
4		Total	2	6	2	8	7

As shown in the table above, bird-related outages on the overhead transmission line continue to occur recurrently. In 2023 and 2024, four such incidents were recorded each year, accounting for 50% or more of the total outages. The persistence of bird-induced outages indicates the need for the installation of dedicated protective devices in future.

In contrast, the number of outages caused by insulator contamination has decreased to two or fewer, demonstrating the effectiveness of the anti-contamination measures, particularly the replacement with aerodynamic insulators.

Weather-related outages have shown an increasing trend since 2021, with three events recorded in 2024. This trend is associated with increased wind speed and frequency, and it also indicates a growing risk of mechanical fatigue and potential conductor failure.

Conclusions

Major maintenance work was carried out on the 110 kV Dalanzadgad overhead transmission line, including the replacement of the lower insulators of all three phases on suspension towers with aerodynamic-type insulators. Following these improvements, outages caused by insulator contamination decreased significantly, from 15 events before 2022 to only 2 events after 2022, representing an 88% reduction.

In addition, conductors with a high number of compression splice sleeves and protective coatings were replaced on an anchor-span basis. As a result, the number of locations affected by compression splice sleeves decreased by 59.2%, while those with protective coatings decreased by 34%. These improvements contributed to an estimated reduction of approximately 11% in conductor losses along the transmission line.

During the study period, a total of 46 outage events were recorded, including 21 events caused by bird-related factors, 17 by insulator contamination, and 8 by weather conditions. Bird-related incidents accounted for 45.6% of all outages, making them the most significant cause.

Based on these findings, it is recommended to install bird protection devices along the transmission line. In addition, designated nesting structures should be provided in areas where bird-related outages have occurred, as well as in nearby locations along migratory routes, in order to reduce further incidents.

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