Feasibility Study on Quality Standards for Patrol and Inspection Transmission Lines by Helicopter

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Abstract. The framework for the basic content of quality standards for patrol and inspection by helicopter in power industry is designed through the analysis carried out to the current status of patrol and inspection business of the State Grid Corporation of China, especially the problems in aspects such as false alarms of defect, lack of standardization in descriptions of defective photos, abandoning of aviation and carryover lines, untimely submission of products, and incomplete submission of products, etc., and on the basis of the method of correlation analysis and analysis of factors of influence. And based on that, it formed the inner quality standard of the State Grid Corporation of China are formed.

1. Introduction
Higher and higher demands are proposed on the power industry due to the sustained and rapid development of the economy in China. However, the urgency of the automation and modernization of maintenance and inspection of lines has been increasingly shown because that it is vast for the territory, complicated for the terrain, has few plains, a lot of hills and mountainous areas, and is complicated for meteorological conditions in China.

The transmission lines have many distribution points, cover a wide range, are located in complicated terrain, and have severe natural environment. The power lines and pole-tower accessories of the transmission lines are exposed in the open for a long time, and therefore are subjected to damages such as falling of towers, strand breakage, wear and tear, corrosion, stress, etc. due to continuous mechanical tension, lightning strikes, aging of material, and man-made effects, and therefore must be repaired or replaced in timely manner. There are also incidents such as damage to insulators due to lightning strikes, discharge of transmission lines due to the trees’ growth, and pole-towers’ being stolen, etc., which must be handled in a timely manner. There is not only a heavy workload but also a difficult condition required for the traditional method of manual patrol and inspection, especially for patrol and inspection of transmission lines that are located in mountainous areas and are stepping over large rivers and lakes, as well as the patrol and inspection during ice damages, floods, earthquakes, landslides, and night, which takes a long time, requires high labor costs, has high difficulties and high risks. It has been acceptable to many industry peers for carrying out the patrol and inspection of transmission lines by using the helicopter, and it is also an important embodiments of power modernization for the maintenance and inspection of transmission lines by helicopter.
Through the implementation process of routes for cruising of helicopter for many years, a set of standards for power industry, state grid enterprise standards and relevant guidelines and manuals of State Grid General Aviation Company Limited, which are currently valid, have been created.

2. Overview of Study
In terms of scope and fields of application of the standards, the current product quality standards in China mainly include: international standards, national standards, industry standards (or standards issued by Ministry) and enterprise standards, etc.

It was carried out earlier for the business of patrol and inspection by helicopter abroad for the power industry, and products of patrol and inspection mainly include defect photos, laser scanning, Digital Elevation Model (DEM), Digital Orthophoto Map (DOM), etc. However, it has not seen the release of product quality standards.

In China, the business of patrol and inspection by helicopter for power industry was firstly carried out by the State Grid Corporation. The business has been carried out for many years, and therefore it is gradually mature for the business process and the patrol and inspection products. The patrol and inspection products include photos and information of defect of patrol and inspection, laser scanning, DEM, DOM, analysis report of dangerous points, analysis report of defect, 3D display system of cruise channel and defect library management system of patrol and inspection.

At present, there is no product quality standard for helicopter patrol and inspection products in power industry at home and abroad, and there is difference for the quality of products implemented by different unit, therefore, it is urgent to form a product quality standard.

3. The Necessity of Normalizing the Standards of Patrol and Inspection
Improve the degree of matching between production planning and required time of customer. Clarify the requirements of the power-off maintenance time and inspection time of the headquarters and provincial companies of the State Grid Corporation, and carry out classification according to the demand level. The company should try to have the demands of the customers satisfied when it arranges its production plan, and strive to have the matching of required time by the patrol and inspection plan accurate to by month from by quarter. Develop a module that operation and dispatching match the production in the dispatching command system.

Reduce the mileage of abandoned aviation routes gradually. Sort out the information of the abandoned aviation routes over the years, and classify the information according to the reason of abandon so that sections whose aviation are abandoned permanently can be clarified, and the planning and arrangement for patrol and inspection can be communicated with customer in advance so as to reduce the occurrence of situation of abandoning aviation after signing the contract. The other substitute means of patrol and investigation such as unmanned aircraft, etc. shall be actively adopted so as to minimize the decrease in operating revenue caused by abandoned aviation.

Promote the submission and the timeliness of patrol and inspected products. Firstly, normal period from the ending of work outside the helicopter to the time for the delivery of the results and the normal period for delivering the results to the customer shall be developed; secondly, the process for transfer of data shall be optimized and analyzed so that the data transfer mode can be explored and innovated and there is the possibility of shortening the data processing cycle; thirdly, it shall establish the transfer mode for the transferring of patrol and investigation data of lines of assets outside the province to the operation and maintenance unit and the asset unit for part of the provincial company.

Enhance the quality of the patrol and inspection operations and the quality of the results. The quality standards and achievement standards for patrol and inspection operations shall be established, the normalized forms of patrol and inspection products shall be set up, so as to facilitate the crew members to have the quality of operations improved and have the quality of results of patrol and inspection raised, and at the same time realize the standardized transfer of patrol and inspection products.
4. Basis for Formulation of Standards

4.1. Analysis of Correlation
As for the data relation, it includes the deterministic dependence, namely, a functional relation, for example, the expression form of relation of \( Y = f(n) \), and a non-deterministic dependence, namely, the correlation analysis (the scatter diagram, the coefficient of relation, the significance verification, and the analysis of regression). As for the functional relation, it describes the fact that under the situation when a certain value is taken for one or more variables, there will be a uniquely determined corresponding value for another variable. As for correlation analysis, it refers to the implementation of analysis to two or more variable elements with correlation so as to carry out the measurement of the relevant closeness of the two variable factors. The calculation formula of correlation is as follows:

\[
 r = \frac{\sigma_{xy}}{\sigma_x \sigma_y}
\]  
(1)

According to the definition of the relevant parameters, the final expression can be derived as follows:

\[
 r = \frac{xy - yx}{\sqrt{\sum x^2 - (\bar{x})^2} \cdot \sqrt{\sum y^2 - (\bar{y})^2}}
\]  
(2)

If there are equations as follows:

\[
\begin{align*}
L_{xy} &= \sum (x - \bar{x})(y - \bar{y}) = \sum x y - \frac{\sum x \sum y}{n} \\
L_{xx} &= \sum (x - \bar{x})^2 = \sum x^2 - \frac{(\sum x)^2}{n} \\
L_{yy} &= \sum (y - \bar{y})^2 = \sum y^2 - \frac{(\sum y)^2}{n}
\end{align*}
\]  
(3)

The expression can be simplified as:

\[
 r = \frac{L_{xy}}{\sqrt{L_{xx} L_{yy}}}
\]  
(4)

The related coefficient is restricted as:

\[-1 \leq r \leq +1\]  
(5)

It has properties as follows: when \( r > 0 \), it indicates that it is positively correlated for the two variables; when \( r < 0 \), it is negatively correlated for the two variables. When \(|r|=1\), it indicates that it is completely linearly related for the two variables, that is, it is functional relation between them. When \( r = 0 \), it indicates that there is no linear correlation between the two variables. When \( 0 < |r| < 1 \), it indicates that there is a certain degree of linear correlation between the two variables. And if \(|r|\) is closer to 1, it is closer for the linear relation between the two variables; if \(|r|\) is closer to 0, it indicates that it is weaker for the linear correlation between the two variables.

In general situation, it can be classified into three levels: if \(|r|<0.4\), it indicates a low degree of linear correlation; if \(0.4 \leq |r| < 0.7\), it indicates a significant correlation; if \(0.7 \leq |r| < 1\), it indicates a high degree of linear correlation.

It is hard to carry out the description to the defect of patrol and inspection from the direction of functional relation based on the defect type, defect level and combined with the historical experience of patrol and inspection and the various causes of the defect; the Hadoop-based correlation analysis method is adopted to carry out the defect data analysis combined with increasing the data volume of the defect data, the special area type of the power grid and the speed and efficiency analysis. The Hadoop-based defect data analysis program is developed by application of Hadoop technology, and the correlation coefficient between the defect type and the special areas of various grids is calculated on basis of the correlation coefficient calculation formula, and is eventually displayed in the form of a graph in the defect library system.
From the defect data of the whole company over the years, it can be seen that it is the data of thematic map of some provinces for the special area data of the power grid. If carrying out the analysis to the correlation between the contaminated area and the type of defect, then the form of the result is shown as follows:

![Correlation curve of defect type](image)

**Figure 1.** Correlation curve of defect type

### 4.2. Factors of Influence

Aiming at the patrol and inspection mode of helicopter, the factors of influence are summarized, a practical and effective benefit evaluation model is set up so that the effectiveness of patrol and inspection under different factors of influence is evaluated by inputting relevant data, and effectiveness evaluation model for patrol and inspection by helicopter can be built so as to determine the optimal patrol and inspection mode under different power environments.

The restricted conditions include the same line, the same time period, and combination conditions. As for the same line: it is of course same for the frequency of the failure occurred in the transmission line for the patrol and inspection on the same line if compared with the manual patrol and inspection. In other words, it the assumption of consistent the natural environment and failure frequency conditions. As for the same time: the same patrol and inspection line is completed in the same time period. The time of patrol and inspection by helicopter for one time is taken as a fixed study period, in other words, it is the assumption of consistency in urgency of time. As for the combination conditions: For the completion of patrol and inspection of specified lines by one helicopter, and the number of inspection personnel is up the total number of people required for completing the inspection within the fixed time of study for the specified lines for the patrol and inspection of the helicopter. In other words, it is the assumption of realization of a targeted combination of certain number of personnel.

Aiming at the patrol and inspection mode by helicopter, the factors of influence are summarized generalized and quantitatively determined. The cost analysis of patrol and inspection mode of helicopter is conducted by setting up practical evaluation model for different cost analysis, and the comparison of economic benefits shall be carried out with patrol and inspection of specific type of helicopter. Cost is used as an important basis for benefit decision-making and also the basic data for model verification. The evaluation of factors of influence of evaluation of artificial experience combined with comprehensive evaluation shall be established so as to minimize the influence of focusing on manual factors, and effectively carry out effectiveness analysis evaluation for the patrol and inspection mode of helicopter, and select an evaluation model which is more appropriate for patrol and inspection. Aiming at the factors of influence for patrol and inspection of helicopter, the neural network evaluation model is selected. It selected multiple patrol and inspection samples of helicopter, to generalize the standard samples, so as to determine the relevant efficiency evaluation parameters; aiming at the sample sequences, it built the neural networks and established an evaluation model. The field data inspection was carried out to the built evaluation of model to verify the correctness of the method, so that it is expected to provide theoretical, data support and guidance for future helicopter, unmanned aircraft and patrol and inspection mode with manual collaboration. The analysis and conciseness are carried out to the influence of factors for patrol and inspection of helicopter, together with the quantitative agreement factors of influence for the patrol and inspection of helicopter, it is basically clear for the causal relation.
However, it is the specific application of high-tech for patrol and inspection by helicopter, and it is relatively fast for the development of the technology, especially, it is rapid for the development of patrol and inspection equipment and post operation and service systems. It is impossible to determine the number and extend by adopting methods such as ordinary modeling, giving marks by experts, etc. At the same time, there are many related factors for each factor, and it is complex for the relation between factors, and therefore it is difficult to determine the weight between these factors.

Therefore, the modeling by adopting the neural network model with memory function is able to have the model more perfect along with the continuous development of the scientific and technological level of helicopter for patrol and inspection, and to raise the accuracy of efficiency evaluation.

5. Framework of Contents of Standard

5.1. Working Conditions and Indicators
It can be divided into regular inspection, acceptance inspection, special inspection of channel, laser scanning for the working conditions of patrol and inspection. It includes electronic documents and hard copies of documents for the reports issued for various working conditions.

The quality standards for the route of regular patrol and inspection include the punctuality rate of completion, the cruising speed, the percentage of decline in defect rate in 100 kilometers, the number of accidents, the defect report, and the analysis report for defect. The patrol and inspection mode for acceptance includes the punctuality rate of completion, the cruising speed, the defect rate in 100 kilometers, the number of accidents, the defect report, and the analysis report for defect. The special patrol and inspection mode of channel includes the punctuality rate of completion, the cruising speed, the number of potential hazards of channel, the number of accidents, the defect report, and the analysis report for defect. The laser scanning mode includes the punctuality rate of completion, the cruising speed, the number of potential hazards, the number of crossings, the number of accidents, and the analysis report of laser scanning.

5.2. Form of Work Results
Lidar data: Lidar data format, standards for organization structure of catalogue, display of results can be carried out. Video data: video data format, resolution, frames per second, standards for organization structure of catalogue. Image data: defect image format, resolution, standards for organization structure of catalogue, entry of defect library system. Analysis report: Including electronic files and hard-copies of documents.

6. Conclusion
Through the analysis carried out to the current situation of the patrol and inspection business of State Grid Corporation, and on the basis of the analysis method of correlation analysis and factors of influence, it designed the framework of basic content, main indicators and form of work results for the quality standards for patrol and inspection of helicopter in power industry.

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