Journal of Engineering Research and Reports

Volume 26, Issue 5, Page 83-92, 2024; Article no.JERR.115235
ISSN: 2582-2926

Research Status and Development Trend of Obstacle Crossing Mechanism of HV Transmission Line Inspection Robot

Baoen Tong [a*]

[a] *North China University of Water Resources and Electric Power, Zhengzhou, Henan, China.*

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JERR/2024/v26i51137

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/115235

Review Article

Received: 01/02/2024
Accepted: 03/04/2024
Published: 05/04/2024

ABSTRACT

With the rapid development of the power grid industry, the traditional manual inspection method is gradually being replaced by intelligent robot technology, which has been widely concerned around the world. The research of inspection robots aims to improve the efficiency and safety of transmission line inspection, while reducing labor costs and quickly identifying potential risks. The obstacle crossing mechanism of inspection robot is the core part of normal inspection of robot. This paper analyzes the obstacle crossing mechanism of inspection robot developed at home and abroad, summarizes the types and characteristics of the obstacle crossing mechanism, and finally puts forward the development trend of the obstacle crossing mechanism of inspection robot

Keywords: Inspection robot; obstacle crossing mechanism; development trend.

**Corresponding author: Email: 2671685021@qq.com;*

1. INTRODUCTION

High-voltage transmission lines carry electricity from power stations to residential and industrial areas [1]. Compared with the overhead transmission system, the underground transmission system is safer and more reliable, but the cost is higher. Therefore, in the world, overhead transmission lines are more commonly used for electricity transmission. The country's terrain is divided into mountains, hills, basins and plains, which inevitably creates the need for overhead power lines to cross harsh environments (deserts, mountains, rainforests and glacial snow) [2]. In these harsh environments, it is installed on vertical poles and towers, using insulator strings, shockproof hammers, overhanging wire clips, etc.

In order to ensure the normal operation of the power lines, it is necessary to carry out routine checks on the lines regularly to detect faults and maintain them early. The traditional way is to manually climb the wire, detect the fault or perform routine maintenance. Manual crawl detection is the most common detection method in the world, however, this puts the lives of workers in danger, possibly falling off the line or electrocuting. Manual inspection sometimes needs to outage high-voltage lines, causing losses to society and enterprises. Due to long-term exposure to the outdoors, transmission lines are vulnerable to the influence of climate and birds and animals, resulting in power outages. In the United States, every half hour of power outage will cause an average economic loss of $15,707 for large and medium-sized industrial enterprises, and every eight hours of power outage will cause an economic loss of nearly $94,000. [3] There is another reason, manual inspection efficiency is not high [4]. Therefore, this has prompted researchers in various countries to study the alternative to manual inspection, resulting in robot inspection.

Robot inspection has the advantages of low cost, high speed and high safety [5]. However, when using robots for inspection, the problem is whether it can bypass the inherent obstacles associated with the line and inspect the line with high accuracy in the shortest possible time. Therefore, combined with the research of inspection robots at home and abroad, this paper analyzes the obstacle crossing mechanism of robots, and summarizes its structural characteristics and development trend.

2. RESEARCH STATUS OF OBSTACLE CROSSING STRUCTURE OF INSPECTION ROBOTS ABROAD

Foreign research on inspection robots began in the late 1980s. In 1988, Tokyo Electric Power Company SAWADA et al. developed inspection robots for high-voltage lines, as shown in Fig 1.[6] It overrides obstacles such as shock hammers and towers on the line by carrying an expandable curved robotic arm, clamping wheel and balancing device [7]. The robot mainly relies on the arc-shaped arm in crossing the tower.When it meets the tower, it spreads the arc guide rail on the power lines on both sides of the tower, loosens the wheels, and makes the robot leave the power lines, move along the arc guide rail, and cross the tower.After crossing the tower, the wheels are reattached to the power line, and the guide rails will detach from the power line and fold up.When working on power lines, for the shock hammer, the robot chooses to roll directly over.

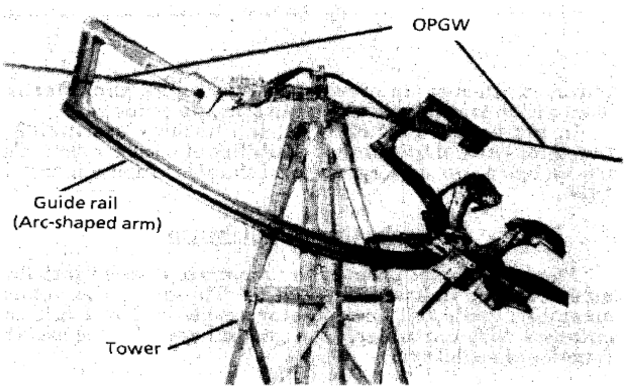

Fig. 1. Robot crossing the tower diagram

In 1991, H KOBAYASHI et al. designed an autonomous decentralized control robot with an earthquake-proof structure. In 1998, PEUNCSUNCWAL et al. in Thailand designed an autonomous inspection robot that could sense the voltage of the transmission line as a power source [8]. In 1999, the American TRC company designed a cantilever automatic inspection robot, which does not have the ability to climb and overcome obstacles [9]. In 2002, CAMPOS and others in Brazil developed a mobile robot for installing and removing aircraft warning balls on aerial power lines [10]. These inspection robots do not have the ability to overcome obstacles and can only work on power lines, so the scope of use is limited.

Hibot, a Japanese company, followed the OPGW inspection robot in 2008 and designed a Hibot Expliner inspection robot that walks along a 2/4 split wire [11]. By adjusting the position of the center of mass, the robot can keep the dynamic balance in the working state and pass the obstacle.This robot can only work between poles and towers. For poles and towers with drainage lines, it is necessary to install bridge guide rails, which is cumbersome to cross obstacles. The obstacle crossing process between poles and towers is shown in Fig 2.

1) The robot recognizes the obstacle.
2) The counterweight of the robot moves to the rear, so that the center of mass moves to the rear of the entire body, and thus the forearm is raised.
3) The robot's forearm rotates so that it moves away from power lines.
4) The robot moves forward, allowing its forearms to cross the obstacle.
5) The robot's forearm rotates to bring it back into position.
6) By adjusting the movement of the robot's counterweight, the forearm falls back onto the power line and returns to its normal position. The back arm moves the same as the forearm.

In 2008, Hydro-Quebec of Canada designed the Line Scout remote control inspection robot based on the successful research of HQ Line Rover remote control car. [12] The Line Scout is built around three separate frames, with the wheel frame (blue) comprising two electric rubber wheels as traction wheels.The arm frame (white) supports two arms and two grippers.Finally the center frame (white circle) connects the first two frames together and allows them to slide and rotate. The obstacle crossing action is shown in Fig 3.

1) The robot stops in front of the obstacle, and the safety wheel (represented by a small rectangle) between the two traction wheels is firmly clipped to the wire, so that the robot is stably fixed to the power line.
2) The arm frame and center frame slide forward and rotate slightly so that the two grippers are located on either side of the obstacle.
3) The arm is raised to power line height while the clamp is clamped on it, the safety roller opens, and the mechanism folds to allow the traction wheel to shrink under the high voltage line. Finally, the wheel frame moves on the center frame to the opposite side of the obstacle.
4) The mechanism deploys and pulls the traction wheel back onto the wire so that the safety roller is again secured to the power line so that the gripper can be safely opened. The arms then return to their original lowered position. Once the boom and center are back in the middle, the vehicle is ready to continue rolling along the line.

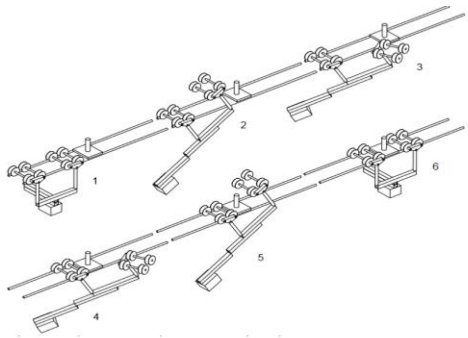

Fig. 2. Expliner robot crossing obstacles

In 2018, Hydro-Quebec Canada developed a new inspection robot Line Ranger, whose obstacle avoidance method is revolutionary.[13] The robot's four wheels on the high-voltage line are tilted in contact with the power line, and when it encounters an obstacle, its arms are passively spread and the wheels roll over them. During this phase, three-bladed rotors provide temporary support on both sides of the obstacle. Using a push rod, a spring under the robot exerts a compressive force on the arm, counteracting gravity and keeping the robot stable on the conductor. Fig 4 shows the simplified obstacle crossing process of the two-wheel system:

1) The LineRanger is close to the overhang line clamp, the wheels are positioned correctly, and the central blade points to the inside of each conductor.
2) The robot begins to roll on the wire clamp. When the central blade touches the wire clamp, the wheel begins to rotate passively, making the robot roll forward relying on the blade.
3) When all the blades pass through the overhang line clip, the spring inside the wheel will exert pressure on the wheel, making the wheel return to the position of contact with the power line, and maintain normal walking.

The high-voltage transmission line is composed of transmission wire, tower, shock hammer, insulator string, suspension clamp and other components, which are obstacles in the normal operation of the inspection robot.[14]Based on whether the obstacle is on the high-voltage line, the obstacle can be divided into tower obstacle and power line obstacle.Therefore, the obstacle crossing structure can be divided into the crossing tower structure and the non-crossing tower structure.[15]Recently, the inspection robots disclosed abroad can overcome obstacles between poles and towers in terms of obstacle crossing structure.Early robots, though capable of overstepping the tower, were too complex.For vertical insulator string (Fig. 3), Expliner robots in reference 8, LineScout robots in reference 9 and LineRanger robots in reference 10 can directly cross obstacles, but for horizontal insulator string (Fig. 5), no good obstacle crossing mechanism has been developed abroad.

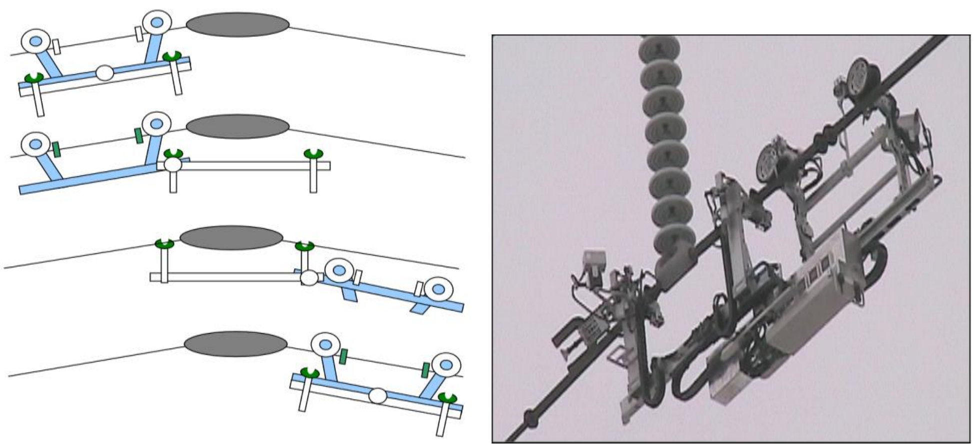

Fig. 3. Line Scout robot crossing obstacles

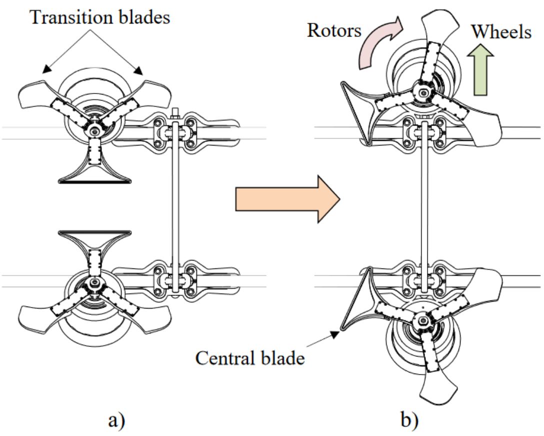

Fig. 4. Line ranger crossing the barrier

Fig. 5. Hanging insulator string horizontally

3. RESEARCH STATUS OF OBSTACLE CROSSING STRUCTURE OF INSPECTION ROBOT IN CHINA

Domestic research on inspection robots began in the 1980s, with Wuhan University, Shenyang Institute of Automation of the Chinese Academy of Sciences, Shandong University of Science and Technology, Institute of Automation of the Chinese Academy of Sciences and Shandong University and other scientific research units mainly developing transmission line inspection robots [16].

Wuhan University has developed two types of inspection robots, traversal inspection robot and leapfrog inspection robot [17]. The traversing inspection robot is composed of a walking mechanism, a pressing mechanism, a moving mechanism, etc. The two arms are suspended on the same side. The obstacle crossing mode is direct rolling through the obstacle (bridge structure is added on the anti-vibration hammer, suspension line clamp and pole tower after modification according to the obstacle crossing structure of the robot) [18]. The obstacle crossing structure is composed of two motor driven compression wheel, driving wheel and sliding table, which work cooperatively to overcome the obstacle. Fig 6 shows the obstacle crossing process of the robot by taking the overhang clamp as an example:

1) After detecting the overhang clamp, the robot detects the robot's tilt slope under the current attitude. If it is not greater than 8°, the robot lowers the clamping wheel and chooses to roll directly over the overhang clamp. After the walking wheel passes, the clamping wheel rises, so that the high-voltage wire is firmly between the walking mechanism and the clamping mechanism.
2) If it is greater than 8°, the robot chooses to move forward in the way of creeping, and the front and back arms move slowly close to the sliding platform. Then, the back arm presses the high-voltage wire, making the forearm release the high-voltage wire, and the sliding platform moves, driving the forearm to cross the overhang line clamp. The same goes for the back arm over the overhang clip.

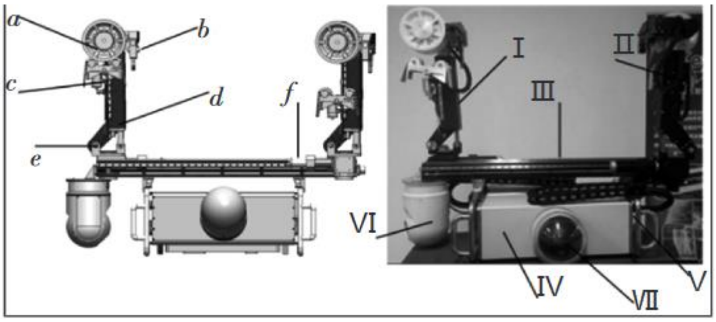

Fig. 6. A robot leaps over obstacles at Wuhan University

I. mechanical arm II. rotating mechanism III. mobile platform IV. control cabinet V. travel mechanism VI. Camera VII. balancing device

The straddling robot of Wuhan University adopts a two-arm structure with antisymmetric suspension, and its obstacle crossing mechanism is composed of a walking wheel, a lifting arm and a rotating mechanism.[19]For obstacles on high voltage lines such as shock hammers, the robot rolls through directly with the help of compression and relaxation of the compression wheel.For the overhang clamp and the string of insulators, the robot crosses the obstacle alternately by rotating its arms.Its obstacle crossing process is complicated, poor security and low efficiency, so the use of this obstacle crossing method is limited. Fig 7 shows the process of the robot crossing the overhang clamp.

1） The robot detects the overhang line clamping obstacle, and the clamping mechanism of the forearm (ii) performs clamping.
2） The rear arm (I) rises, allowing the wheel to leave the high voltage line.
3） The rotating mechanism of the forearm (Ⅱ) rotates so that the rear arm (Ⅰ) rotates onto the high voltage line in front of the obstacle.
4） The back arm (I) descends, falls to the high voltage line, the clamping mechanism of the back arm (I) is clamped, the forearm (II) crosses the obstacle in the same way, and finally crosses the obstacle, and the robot walks normally.

The Shenyang Institute of Automation of the Chinese Academy of Sciences began to develop inspection robots in 2002, and developed AApe series of inspection robots along overhead lines.[20-23]This series of robots generally use wheels and robotic arms to climb similar to the way apes climb tree trunks.[24]The robot adjusts its own balance through the center of mass to achieve smooth obstacle crossing, and can cross obstacles such as overhanging wire clips and shock-proof hammers. However, for the string of cross-hanging insulators in the tensioning pole tower, the robot uses the drainage line under the tensioning pole tower to cross the obstacle. Fig 8 shows the process of the robot crossing the single overhang clamp:

1） The robot detects an obstacle, stops, and the center of mass regulating mechanism moves to the rear arm, causing the front wheels to rise. The front wheel rotary joint rotates, keeping the forearm away from the high-tension wire.
2） The rear wheel drives the robot forward. After the front wheel crosses the obstacle, the front wheel gyrate joint rotates while the front wheel falls on the high voltage line.
3） The center of mass adjustment mechanism moves to the forearm, causing the rear wheel to rise, and the rear wheel rotary joint to rotate, causing the rear arm to move away from the high-voltage wire.
4） The front wheel drives the robot forward. When the rear arm passes the obstacle, the rear wheel rotates through the rotary joint. At the same time, the rear wheel falls on the high-voltage line, and the robot carries out normal inspection.
5） The robot uses the expansion and contraction of the robot arm to make the wheel fit with the drainage line when passing the drainage line. When the drainage line is falling, the walking mechanism is used to grip the drainage line, and the center of mass adjustment of the control box is used to make the robot have a suspended trend, so that the robot can walk on the drainage line in the way of alternating front and back arms.The crawling drain works the same way.

Fig. 7. Leap-over robot in Wuhan University

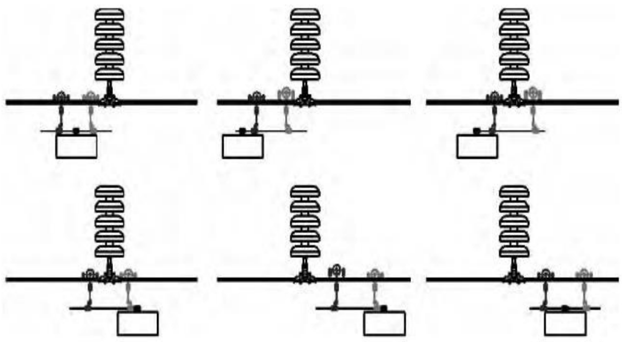

Fig. 8. The robot overhangs the clamp with the insulator string

Shandong University of Science and Technology in 2019, the latest development of a bionic robot, imitation inchworm motion inspection robot.[25,26] The developed robot can not only overcome the obstacle in the straight section of the high voltage line, but also better cross the tensioning tower along the drainage line.The obstacle crossing structure is forearm, middle arm gripper and back arm.When the forearm crosses the obstacle, the back arm stays on the high-voltage wire, the middle arm gripper grabs the high-voltage wire, the forearm leaves the high-voltage wire, and relies on the back arm and the middle arm to maintain the balance of the robot to walk. After crossing the obstacle, the forearm finds the appropriate position to lower the arm, and then the back arm crosses the obstacle in the same way. In addition to the anti-shock hammer, the robot chooses the inchworm wriggling motion to complete the robot's two arms alternating over the obstacle. Fig 9 illustrates the obstacle crossing process of the robot with the overhanging wire clip and the drainage wire.

Overhang line clipping:

1) When the robot detects an obstacle, it stops, and the middle arm gripper moves to the front of the obstacle to grasp the line.
2) The forearm is removed from the line, and the robot relies on the back arm and the middle arm to hang on the line, so that the whole body moves forward while maintaining balance.
3) After crossing the obstacle, the forearm returns to the high voltage line, the middle arm releases the line and moves forward. After crossing the obstacle, the middle arm grabs the line in front of the obstacle in the same way, and the back arm crosses the obstacle in the same way. After the back arm crossed the obstacle, the middle arm left the line, and the robot maintained a normal walking gait.

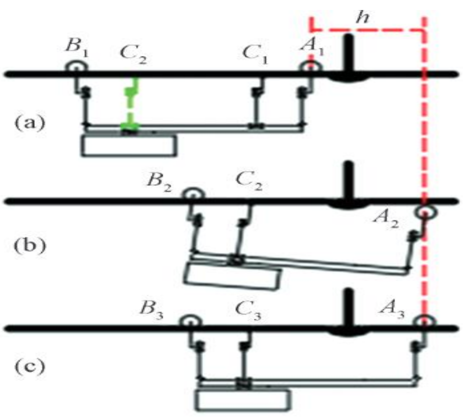

Fig. 9. Robot overhang wire clip and drainage wire

Robot across the drainage line:

1) When the robot is at the lowest point of the drainage line, the current state of the robot is the initial state. The robot keeps walking normally, walks to the right position, and the robot stops moving forward.
2) Move the middle arm forward to grab the line.The box moves to the rear end of the slide rail to balance the robot, the forearm is off-line, and the robot relies on the back and middle arms to keep moving forward.
3) When the middle arm moves to the junction of the transmission line and the drainage line, the forearm returns to the line, the middle arm disconnects, and the robot relies on the forearm and the back arm to keep walking.
4) When the back arm walks to the junction of the transmission line and the drainage line, the robot stops, the middle arm grabs the line, the box moves to the front end of the slide rail, the back arm performs off-line processing, and the robot keeps moving forward in the balance state of the forearm and the middle arm.
5) After the back arm crosses the interchange point, the robot stops, the back arm returns to the line, the box returns to the initial position, the middle arm is off the line, and the robot carries out normal walking inspection.

In addition, there are some domestic scientific research institutions and universities, Shanghai University, North China Electric Power University, Sichuan University, etc., have carried out certain research on transmission line inspection robots, and have made certain achievements in the obstacle crossing structure.

4. CONCLUSION

In summary, with the development of modern science and technology, the development of domestic inspection robots is also updated from generation to generation. The existing robots are relatively mature when crossing simple obstacles on high-voltage lines (such as shockproof hammers, overhanging wire clips, etc.), but for the barrier crossing of tension-resistant poles or drainage lines, certain efforts are still needed.The obstacle crossing mechanism which has been developed at present is summarized, which can be divided into wheel arm compound type, bionic climbing type and multi-position cooperative type. Wheel arm compound type is more common, because it is faster than other methods, simple structure.The obstacle crossing methods can be classified into climbing (inchworm imitation robot of Shandong University of Science and Technology), horizontal crawling and rotating (two-arm inspection robot of Wuhan University), and direct rolling obstacle crossing (Line Ranger robot of Canada).

FUTURE TREND

1) Less freedom.The obstacle crossing mechanism of the inspection robot will be designed to have fewer degrees of freedom, which will facilitate obstacle crossing and easier operation.
2) Wide use. The robot's obstacle crossing mechanism can not only cross obstacles, but also adjust the robot's self-state on the power line (such as U-turn, emergency brake, etc.).
3) Multi-functional. The obstacle crossing mechanism of the robot is not only suitable for the obstacle crossing of single wire, but also suitable for the obstacle crossing of 2/4 split wires.
4) New structure.The obstacle crossing method is combined with the flight mechanism. For the hanging line clip, the cross-hanging insulator string and the pole tower, the flight mechanism carried by the robot can be used to cross the obstacle.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Zhang Lu. Path planning problem of multi-station UAV group under composite type inspection task. Master degree, Chang 'An University; 2023. Available:https://doi.org/10.26976/d.cnki.gchau.2022.000894.
2. Alhassan AB, Zhang X, Shen H, Xu H. Power transmission line inspection robots: a review, trends and challenges for future research. International Journal of Electrical Power & Energy Systems. 2020;118: 105862.

Available:https://doi.org/10.1016/j.ijepes.2020.105862.

3. Nguyen VN, Jenssen R, Roverso D. Automatic autonomous vision-based power line inspection: A review of current status and the potential role of deep learning. Int J Electr Power Energy Syst. 2018;99:107-120.
4. Wang Zhiwei; Zhang Zhenmeng; Jia Yanhao; Fu Penghao; Sun Aiqin; Yuan Liang. Energy Consumption analysis and optimization of wheeled robot based on Matlab/Simulink simulation. Journal of shandong university of science and technology (natural science edition). 2023; 42(5):97-107. Available:https://doi.org/10.16452/j.cnki.sdkjzk.2023.05.011.
5. Wu Peng. Development of 10KV overhead line insulation repair robot. Master, North China Electric Power University; 2018.
6. Sawada J, Kusumoto K, Munakata T, Maikawa Y, Ishikawa Y. A Mobile Robot For Inspection Of Power Transmission Lines; 2018.
7. Lu Kunyuan, Wang Jidai. Research status and development trend of mechanical structure of high-voltage transmission line inspection robot. Machine Tools and Hydraulics. 2021;49(9):41-45.
8. Peungsungwa S. Autonomous Robot For A P O W R Transmission Line Inspection.
9. Robots Repair and Examine Live Lines in Severe Conditions. Electrical World;(United States). 1989;203:5.
10. Campos MFM, Pereira GAS, Vale SRC, Bracarense AQ, Pinheiro GA, Oliveira, M. P. A Mobile Manipulator for Installation and Removal of Aircraft Warning Spheres on Aerial Power Transmission Lines. In Proceedings 2002 IEEE International Conference on Robotics and Automation (Cat. No.02CH37292); IEEE: Washington, DC, USA. 2002;4:3559-3564. Available:https://doi.org/10.1109/ROBOT.2002.1014261.
11. Debenest P, Guarnieri M, Kensuke Takita, Fukushima E. Shigeo F, Hirose Kiyoshi Tamura, Akihiro Kimura, Hiroshi Kubokawa;Narumi Iwama, Fuminori Shiga.Expliner - Robot for Inspection of Transmission Lines. In IEEE International Conference on Robotics and Automation; IEEE: Pasadena, CA, USA. 2008;3978-3984. Available:https://doi.org/10.1109/ROBOT.2008.4543822.
12. Montambault S, Pouliot N, Lepage M. On the latest field deployments of linescout technology on live transmission networks. In 2012 2nd International Conference on Applied Robotics for the Power Industry (CARPI); IEEE: Zurich. 2012;126-127. Available:https://doi.org/10.1109/CARPI.2012.6473342.
13. Richard et al. LineRanger Analysis and Field Testing of an Innov.Pdf; 2019.
14. Yan Han, Wu Gongping, Cao Qi, Yang Song. Structural design and analysis of high-voltage transmission line rescue robot. Mechanical Design and Manufacturing. 2019;1:20-23+28. Available:https://doi.org/10.19356/j.cnki.1001-3997.2019.01.006
15. Dian S, Chen L, Hoang S, Pu M, Liu J. Dynamic balance control based on an adaptive gain-scheduled backstepping scheme for power-line inspection robots. IEEE/CAA J. Autom. Sinica. 2019;6(1): 198–208. Available:https://doi.org/10.1109/JAS.2017.7510721.
16. Li Zheng. Research on autonomous inspection robot for high-voltage transmission lines. Ph.D., Shanghai University; 2015.
17. He Yuan. Research on an overhead transmission line inspection robot crossing the barrier along the ground line. Dr, Wuhan University;2018. Available:https://kns.cnki.net/kcms2/article/abstract?v=ACks_bcdpKlgjN26Ow2YQ100V5np8oN7bp4i8qPQp_FTXS5xZKmRkVcJUgHFzhfRz6lis0n4nkRZxrWz_HGxTqQw6zEbiyzZqrj4j3dBJJB8SW4b0qzAxgcmG2pcWXv4gVrsctvxCMB3pH2ik4DzQ==&uniplatform=NZKPT&language=CHS (accessed 2024-01-10).
18. Wu Gongping, Wang Wei, Yang Zhiyong. Improved obstacle crossing inspection robot design and obstacle crossing action planning.Journal of sichuan university (Engineering Science). 2015;47(6):157-164. Available:https://doi.org/10.15961/j.jsuese.2015.06.022.
19. Zhang Yijie, Wu Gongping, Xiao Hua, Peng Xiangyang. Research on autonomous obstacle crossing method of leapfrog inspection robot. Mechanical

Design and Manufacturing. 2019;2:242-245. Available:https://doi.org/10.19356/j.cnki.1001-3997.2019.02.061.

20. Fu Shuangfei, Wang Hongguang, Housing fund, Jiang Yong. Research on obstacle crossing control of UHV transmission line inspection robot. Robot 2005;4:341-345+366. Available:https://doi.org/10.13973/j.cnki.robot.2005.04.011.
21. Sun Cuilian, Wang Hongguang;Zhao Mingyang, Tan Dalong. Review on mobile obstacle crossing mechanism of ultra-high voltage line inspection robot. Mechanical Design and Manufacture 2006;10:161-163.
22. Linglie;Wang Hongguang, Li Shujun;Jiang Yong;Song Yifeng. Mechanism design of inspection robot based on the task of transmission line walking over obstacles. Mechanical Design and Manufacturing. 2012;10:84-86. Available:https://doi.org/10.19356/j.cnki.1001-3997.2012.10.032
23. Wang Lusan, Wang Hongguang, Housing fund, Zhao Mingyang. Research on obstacle crossing control of transmission line inspection robot. China Mechanical Engineering. 2007;22:2652-2655.
24. Yue Xiang, Wang Hongguang, Jiang Yong, Zhang Jue, Zhang Chengwei, Xi Ning. Research on a 110kV transmission line inspection robot.Journal of Intelligent Systems. 2016;11(2):155-162.
25. Wang Jidai, Liang Maoxuan, Sun Aiqin, Wang Zhiwei, Liu Yi, Zhang Bin. Obstacle crossing motion analysis of an inchworm type transmission line inspection robot.Science Technology and Engineering. 2020;20(19):7683-7688.
26. Wang Jidai, Liang Maoxuan, Sun Aiqin, Wang Yunxia, Hou Jianguo, Zhang Bin. Autonomous obstacle crossing motion control method of transmission line inspection robot based on finite state machine. Machine Tools and Hydraulics. 2022;50(5): 21-27.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/115235