Study Committee B3

Substations and Electrical Installations

10738_B3_PS3_2022

Development of crawler-type robot for substation inspection

Tetsuya OKAZAKI* Chubu Electric Power Grid Co., Inc.

Ryousuke HATANO Chubu Electric Power Grid Co., Inc.

Keita ITO Mitsubishi Electric Corporation

Takeshi MAEDA Mitsubishi Electric Corporation

Masashi KITAYAMA Mitsubishi Electric Corporation

1. Introduction

- The authors have developed a crawler-type substation inspection robot.
- For electric power companies, reducing O&M (Operation & Maintenance) costs is a major challenge. The authors have developed an UGV (Unmanned Ground Vehicle) to reduce labor costs by automating some inspection tasks.
- Although robots have made remarkable progress in recent years, few of them are capable of autonomous operation outdoors on rough terrain. In this research, crawlers were used for wheels to achieve high traveling performance even on rough terrain. In addition, various sensors such as LiDAR (Light Detection and Ranging) were installed, and have researched about autonomous driving.

2. Expected effects of the robot

- Resilience Improvement.
  Robot can speed up restoration of substation failure, because maintenance workers can confirm the site situation from a maintenance office.
- Reduction of labor costs.
  Robot can take photo while driving along the inspection route automatically. It means maintenance worker's travel and patrol time can be reduced.

3. Substation situations that affect inspection work

- Road surface conditions (not only paved)
  The robot needs to travel on a variety of road surface conditions: asphalt, crushed stones, slopes, rough terrain, etc. Common wheeled type robots can't run well on crushed stones.
- Location of inspection objects
  Some meters are installed in a box with an inspection window or at a high place (1500 mm or more). This makes it difficult to take pictures with a camera from a lower position. The meters are not visible due to blind spots, reflections from the window glass, etc.
  ⇒Cameras need to be raised to eye level.

Fig.1. Crushed stone ground and Inspection window height

4. Configuration of the prototype

4-1 Hardware structure

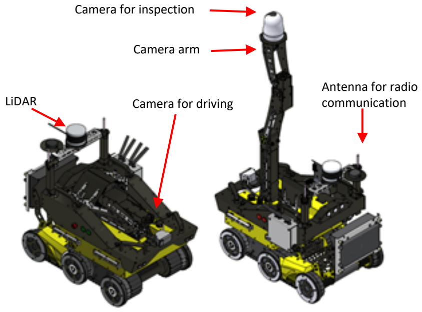

Fig. 2. Overview of the Inspection Robot.

Table 1 Features of the Inspection Robot.

Feature	Explanation
Combination of wheels and crawlers	Can run on both rough and paved roads
Camera arm with height 1500mm	Can check the inside of the inspection window
Sensor for autonomous driving	LiDAR(*) and GNSS(**)
Communication system	Can operate through both WiFi and LTE

(*) LiDAR: Light Detection and Ranging
(**) GNSS: Global Navigation Satellite System

Fig.3. Charging station

4-2. Overview of Autonomous Driving

- Autonomous driving means that robot automatically selects a route and drives to the indicated target point while avoiding obstacles.
- The autonomous driving function utilizes ROS (Robot Operating System), an open-source middleware for robots. A surrounding map is created using LiDAR, and it is compared with the robot`s original. By integrating the map and sensor information such as GNSS, odometers, and IMU (Inertial Measurement Units) , the robot is able to estimate its own position.
- To realize autonomous driving, software improvement and parameter adjustment were necessary according to the characteristics of the robot body and the driving location.

Study Committee B3

Substations and Electrical Installations

10738_B3_PS3_2022

Development of crawler-type robot for substation inspection continued

4-3. Configuration of robot system

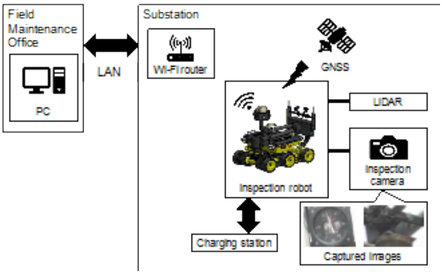

Fig.4 Configuration of inspection robot system

5. Evaluation on the field test

5-1. Results about basic performance

Table.2. Testing methods and results.

Category	Testing methods	Evaluation results
General	Approach the charging station by remote control and connects to the charging port	Good
Driving	Overcoming steps of less than 50mm in height	Good
	Driving on rough roads such as crusher-run stones, asphalt, metal plates, etc.	Good
Control	Remotely controlled by driving camera	Slight delay in the camera image. ⇒reduce the resolution
	Autonomous driving (Detail described in 5.2)	Can travel along a pre-defined route and take pictures at defined points.
Supervising	Capture images of meters via inspection camera	Good

Fig. 5. Field test situation

5-2. Results about autonomous driving

- We mounted an autonomous driving system on a robot and tested it in three substations.
  We investigated the effects of various substation characteristics on autonomous driving.

Table 3 Effects of substation features on autonomous driving

Characteristics	Effects to Autonomous driving
Crushed stone surface	Odometry is sometimes inaccurate (Wheels slipping)
Ducts	Risk of falling (Too narrow for the robot)
Fences, chains	Mistaking it for a passable road (Can't find it because of many gaps)
Slopes	Mistaking the ground for an obstacle (LiDAR beam detect the ground)
Steps	Robot lose its self-position (LiDAR tilt and face the ground and sky)

- The authors solved the above five issues by adjusting various parameters.
- Entering the charging port by autonomous driving was difficult. There were two issues: one was the need for fine control to enter the narrow entrance, and the other was that the charging port itself was recognized as an obstacle by robot. We solved this problem by preparing maps and parameters for parking, different from those for driving

5-3. Series of driving and photography

- To apply robots to substations, the authors developed a function that continuously runs and takes pictures.
- We need to run the robot at the substation and obtain map data and use it to generate an inspection route. Maintenance staff registers the location information of the route and inspection points, as well as the information for taking pictures (angle, zoom, etc.).
- Results at the substation test were generally positive. The robot was able to travel autonomously along a defined route and raise its camera arm at a predetermined position to capture images of the object.

6. Conclusion

- Prototype robot for substation inspection is achieved
- This robot is able to:
  ・Be both radio control and autonomous from a remote location.
  ・Run under various rough ground in substations.
  ・Take pictures while traveling on a inspection course.
- Practical application requires resolution of issues. Improvement of the accuracy of autonomous driving, development of operation management software, etc.