Robot for High Voltage Transmission Line Inspection

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Abstract- The proper maintenance of High-voltage transmission lines is of vital importance, since any problem may result in the interruption of electricity, with many negative impacts to health, transportation and safety and causes a huge loss of capital. Preventive maintenance is the best way to avoid problems with infrastructure, by detecting them in an early stage and responding accordingly with action plans for improvements or repairs. So idea about the Line Inspection bot meets this requirement. It will consist of camera modules; Image Processing techniques are used for detection of faults and cut in conductor, corrosion over conductor or guard ring.

Index Terms- Line Inspection, Image Processing

I. INTRODUCTION

The inspection of high voltage transmission line is a very risky operation, as workers move on the lines several tens of meters above the ground, in very demanding and stressful conditions. The helicopters are used as a way to improve safety and speed of inspection operations. Even though video shot from the cameras placed on the helicopters provides general information regarding the conditions of the lines, and (most importantly) the vegetation around the towers and lines, this method cannot provide details of the lines regarding scratches or minor faults or corrosion, these are early signs of problems that should be repaired before the lines are seriously damaged.

Corrosion is probably the major factor in limiting the life of steel reinforced aluminum conductors used in high voltage transmission lines. Corrosion of conductor lines is accelerated by the effects of local environment conditions. This means that a 50-year-old line may still be in the first stage of its life cycle, while another line, of the same age, could be at the end of its life. Corrosion is caused by local environmental factors such as industrial pollution or salts from a marine or local inland source. Local influences from industrial sites may include contaminants such as grease, localized heating or harsh atmospheric pollutants.

Early detection on live lines with Non-Destructive methods will give early warning of deteriorating conditions thereby enabling the asset manager to implement cost effective maintenance and replacement programs to extend service life. Transmission line corrosion surveys offer significant data to aid an Asset Manager in making safe and cost effective decisions in a risk based program; monitoring the corrosion in the steel reinforcing enables an assessment of entire remaining service life of a conductor. Detection of missing quarter pin is also important as it is used in the nut to support the bolt from loosening and falling down.

So our idea is to make a robot which will run on the transmission line with camera modules mounted on it. The camera modules will take the images which will be used for analysis like corrosion detection, minor faults, etc. So in this way it will help the workers to inspect the line with ease and safety.

II. LITERATURE SURVEY

A. Types of Maintenance

For the inspection of transmission line, we are available with maintenance techniques mainly two types. One is predictive and other is preventive maintenance

1. Predictive Maintenance

To protect the equipment failure is the main aim of our predictive maintenance technique. Other than this it also performs the required maintenance to prevent any occurrence of failure. Monitoring the task for future possibilities of failure helps us to plan the maintenance before any failure occurs. Any of these techniques can help us to predict the on board failure risk. However the technique chosen must predict the failure effectively and at the same time warn us beforehand providing sufficient time to plan and execute our maintenance. The techniques include oil analysis, equipment observation, thermal imaging and vibration analysis. Condition Based Maintenance is used to describe these techniques in detail.

Cost savings are brought by these.

i. Cost of spare parts and supplies is minimized
ii. Production hours lost for maintenance are minimized
iii. Equipment maintenance time is minimized

2. Preventive Maintenance

Preventive maintenance provides care and personal servicing for maintaining equipment and helps achieving satisfactory operating conditions by providing detection, systematic inspection and correction of failure before occurrence and development stages of the equipment. Measurements, parts replacement, including tests, adjustments and maintenance are specifically performed to prevent the occurrence of faults. The most frequent approach is the maintenance at fixed intervals and RCM (reliability - centered maintenance strategies) is the technique recently considered for application. Applications where RCM is used in transmission system approaching to a maintenance strategy using a genetic algorithm.

B. Live Line Maintenance

A policy for overhead line maintenance should be undertaken from the overall maintenance policy, which sets a particular direction for these lines in the form of specific Key Performance Indicators. A constant development in Smart Grid is seen in line maintenance technologies recently. Switching cycle of switchgears can be minimized and line working also helps in reducing the incident risks depending upon the age of the equipment.

This includes

i. Broken glass cap and pin disk insulators are replaced and instead composite insulators like NCI's are used. A large number of broken glass disks are observed mainly due to vandalism occurring in populated rural areas. In Indian transmission, around 80% of live line maintenance activity is done by insulator replacements.
ii. 30% of line faults are experienced because of bird streamer faults and bird pollution. To avoid these flared over insulator strings are expected to be replaced at fixed intervals.
iii. Bundled conductors and spacer/dampers are majorly included in transmission lines.

C. Operational Facts Considered During the Live Line Maintenance

i. To eliminate switching over voltages, auto recloses devices on the line on which the line works are inhibited.
ii. Because of TO V's, thunder and lightning activities do not seem applicable for performing line work.
iii. To reduce p.u. switching over voltages, closing resistors are used on EHV circuit breakers
iv. Series capacitor banks are bypassed because they are proven to have an adverse effect of p.u. overvoltage throughout the line during line faults and switching
v. The values suggested in respective tables in IEC 6 1472 are used when specific determination and simulation of values for variables is not done
vi. Transmission networks are used d to determine one set clearance applied through the using worst case scenarios (e.g. Altitude)

D. Methods of Live Line Maintenance

1. Hot Stick Method (HSM)

In the Hot Stick method the lineman is at the ground potential, who works with the Hot Sticks (tools) keeping safe clearance from the line.

i. Hot Line Maintenance Tools:

Table 1. Hot Line Maintenance Tools

Sr. No.	Tools	Application/Properties
1.	Epoxy glass sticks	• Higher insulation value (100kv/foot / 5 min) • Mechanically stronger • Orange color for easy identification • No effect on the sticks due to sudden changes in temperature or atmospheric condition • Superior than wooden sticks • Handling easy because of light in weight
2.	Hot clamp	Used for preventing movement of conductor cover /guard over the conductor
3.	Conductor cover, insulator cover	IR Value from 35.5 kv – 49 kv
4.	Utility platform	750 lbs. available in 36" & 42"; used on poles with safer distance for working of line men
5.	Hand gloves	20 kv / feet. Can be used up to 11 kv
6.	Epoxy glass rail platform with the provision to	800 lbs.

	tie the safety rope.	

ii. Safe Working Distance for Hot Line Operations as per OSHA Standards

Table 2. Safe Working Distance for Hot Line Operations as per OSHA Standards

Voltage range phase to phase in kv	Meters	Feet
2.1 to 15	0.61	2
15.1 to 35	0.71	2‘4”
35.1 to 46	0.76	2‘6”
46.1 to 72.5	0.91	2‘
72.6 to 121	1.02	3‘4”
138 to 145	1.07	3‘6”
161 to 169	1.12	3‘8”
230 to 242	1.52	2 5‘
345 to 362	2.13	7‘
500 to 552	3.35	11‘
700 to 765	4.57	15‘

2. Bare Hand Method (BHM)

In 1937, Michael Faraday proved that electricity between the two points at the same potential is same. If a Lineman is shielded in a Faraday Cage, and if the cage is bonded to an energized conductor, he may work on the conductor and also associated hardware without shock or discomfort. Here the lineman works at line potential keeping safe clearance from the ground. To implement these method conductive suits made of 25% microscopic stainless steel and 75% nomex are provided. As shown in figure 2.2, two lineman inspecting live transmission line wearing special suit.

3. Combination

Nowadays, a combination of above two methods is used in practice. The HSM & BHM methods are complementary and supplementary to each other. Insulated ladders, insulated aerial platforms, rope hoisting methods and helicopters are utilized to gain access to live conductors and structures. Tools and techniques are developed and optimized for local conditions and designs, which are based on maintenance requirements and available resources.

Here we discussed various methods for maintenance of transmission lines. Every method has some or the other disadvantages. The main disadvantage of all the methods mentioned above is that they are costly, time consuming and delayed detection. Thus we propose a mobile robot system that is based on image processing which provides detection and is also cost effective.

III. PROPOSED IDEA

The inspection of transmission line using the mobile robot which eliminates the risk of any harm to human and provides better results of inspection with the help of image processing. It can move along the transmission line while remaining as light and compact as possible. Line Inspection Bot will consist of camera modules placed on it; Image Processing techniques are used for detection of faults and cut in conductor, corrosion over conductor or guard ring. To achieve such an aggressive target, four fields of technology the robot’s mechanical design, onboard electronics, control system and software for image processing need to be developed.

IV. WORKING

The Robot is autonomous and it moves on the transmission line on its own. Limit switches or IR sensors are used to detect the end of the line. The raspberry also keeps track of its location on the line and sends the location coordinates.

For the transmission of video we have planned to stream raspberry pi camera over a netcat connection. Netcat is a simple tool that helps establish a TCP and UDP connection. There are other techniques for streaming video viz. RTP or RTSP flow with VLC, Gstreamer.

However tests done by others show that the latency ranges from 1500 ms to 4000 ms. even reduction in resolution did not improved the latency. Although Gstreamer gives lesser latency it is not suitable for our project as accessing Gstreamer pipeline from an openCV code is not currently easy. Therefore we have planned to use Netcat which is easy to use with openCV. Also it produces lower latency. On client side (receiver) the video is processed using openCV. The technique used for detection of rust is color detection. Along with the video streaming the robot is also sending the coordinates of the line. When rust is detected the client laptop records the coordinates. Thus the corrosion is detected on the transmission line. Simultaneously the object detection method is used to find the missing quarter pin on the insulator.

V. RESULTS

We have performed the corrosion detection on the line with the help of color detection using python and OpenCV. Given below are the 2 sample images on which corrosion detection is being performed. Similarly corrosion detection can be performed on guard ring, nut-bolt, etc. on the transmission line using various image processing techniques.

The process used for corrosion detection can be given in two steps as:

1. Image Conversion

In HSV, it is easier to represent a color than RGB color-space. So, image is converted from BGR color space (the default one) to HSV color space. There are many color-space conversion methods available in OpenCV. For color conversion, function used is cv2.cvtColor (input image, flag), where flag determines the type of conversion. For BGR to HSV, we use the flag cv2.COLOR_BGR2HSV. After converting the image in HSV format, we can use this to extract a colored object. So, the object in our case is the corroded transmission line and in order to detect it, while specifying the range of color, we have specified the range of brownish color (like corrosion) by trial and error method.

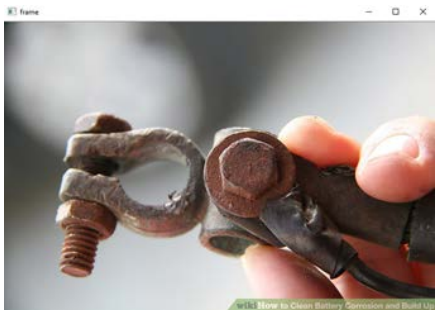

Figure 1. Sample image 1 for corrosion detection

(Source: WikiHow)

2. Masking

Masking the image is basically creating some specific region of the image following certain rules. Here we are creating a mask that comprises of an object in brownish color. Figure 2 shows the mask of image. After that we have used a bitwise AND on the input image and the mask, so that only the brownish colored corrosion is highlighted, as shown in the figure 3 and stored in res. We then display the frame, mask and res on 3 separate windows using imshow function.

Figure 2. Mask on sample image 1

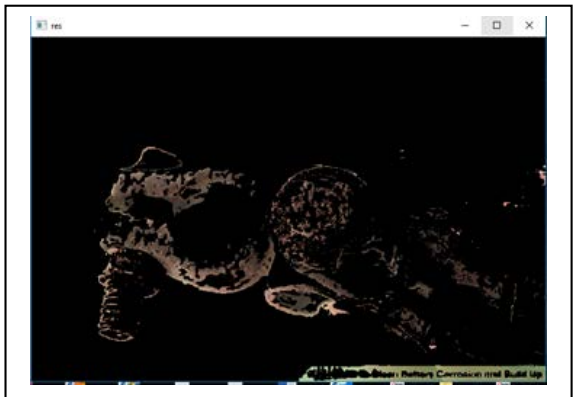

Figure 3. Corrosion Detection on sample image 1

Figure 4, shows the prototype of the robot which can run on the transmission line smoothly on side wheels and can even change the line from one side of the tower to the other crossing the minor obstacle of connectors, with the help of flexibility in the structure.

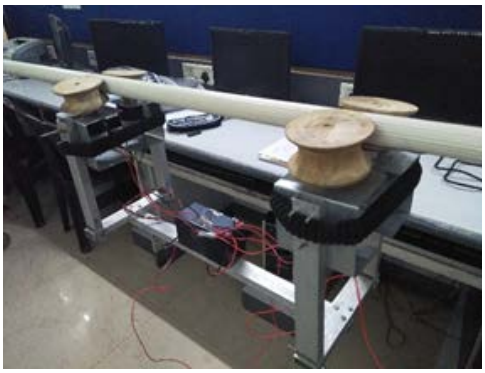

Figure 4. Prototype of the robot

I. CONCLUSION

This paper reveals the importance of Live- Line Maintenance Techniques and also the solution to detect the faults on the line. The idea of the prototype is feasible, carries the weight of the robot and runs smoothly on the line detecting the corrosion on the conductor and detection of missing quarter pin. It is not as costly as compare to the money given to the workers to inspect the lines or the maintenance techniques used nowadays. Therefore this maintenance technology directly improves the quality of service, saves equipment, man power and cost of the maintenance.

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