GRD Journals | GRD Journal for Engineering | National Conference on Emerging Research Trend in Electrical and Electronics Engineering (ERTE'19) | May 2019
e-ISSN: 2455-5703

# Line Inspection Robot

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## Abstract

We all know that electricity is a part of our day today life and its demand has increased considerably due to the rise in the population. In order to supply power to the consumers, it has to be transmitted with minimum amount of losses such that the power system provides better efficiency. For this purpose, generation, transmission and distribution must be efficiently carried out considering all the factors in order to reduce losses and increase the power outcome. Transmission line (TL) plays an important role in transmitting electrical power. This paper deals with the maintenance of overhead (OH) TL by using a robot, which monitors the TL and detects any fault if present, so that electricity is transmitted with minimum amount of losses. Maintenance and detection of any kind of faults in the TL is a difficult task we face then and now because of risky factor while dealing with high voltages. Usually inspectors carry line inspection by aviation method which includes an observer who observes the TL by a helicopter driven by a pilot which is indeed a costly one and the video images provided from the helicopter is out of focus. Hence in order to achieve the same a robot is used which travels on the TL with the help of rollers on it. The robot inspects the TL and transfers the data regarding the line faults directly to the control room. In this method, the robot is equipped with a voltage and current sensor for the measurement of voltage and current, a RF module for communication purposes and a visual camera to capture images to be sent to the control room. This method is so advantageous in reducing cost, increasing efficiency and enhancing safety.

**Keyword- Bundled Conductors, ACSR, Corona**

## I. INTRODUCTION

In recent years, the demand of electricity in our country has increased due to rise in population. To supply power all over is a big task and it can be achieved by reducing the power losses and maintaining the power system efficiency considering human safety and nature conditions. The high-voltage transmission line (TL) connecting electric energy production facilities to large urban centres are vital elements of electrical infrastructure. Any failure in such lines may bring severe consequences to people's daily lives, affecting transportation, health, security and sanitation, to mention just a few. Therefore, the proper maintenance of high-voltage TL is of extreme importance. Preventive maintenance of the lines aims at detecting damages in the case or in the core of the cables, and requires people to walk on the lines a time-consuming and dangerous job, in spite of all the safety procedures applied. In addition, when the lines are being inspected, the transmission of electricity must be temporarily suspended, which means that other lines may be overcharged in order to compensate for the line that is undergoing maintenance.

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 repairs or improvements. However, inspection of high voltage TL is a very risk operation, as workers must move on the lines several tens of meters above the ground, in very demanding and stressful conditions. In order to make this work safer, sometimes the transmission of electricity is interrupted for the inspection operation. However, this may not be possible at all times, since it would overcharge other parallel lines. In times of high demand, such as summer and winter, the utilities may have to pay hefty fines for the reduction in capability to provide electricity. The use of helicopters has been proposed as a way to improve safety and speed of inspection operations. Even though video shot from helicopters provides general information regarding the conditions of the lines, and the vegetation around the towers and lines, this method cannot provide details of the lines regarding scratches, minor faults or corrosion, which are early signs of problems that must be repaired before the lines are seriously damaged.

We introduce a robot for the purpose of monitoring the TL in real time conditions. The robot travels on the TL with the help of rollers and it will be suspended on TL. The utilization of human being is minimized by using robots. The robot can overcome from any obstacles on PLs for this rigid robots having cameras for thermography image processing, power sources and power sensors are included. Maintenance of overhead (OH) TL is difficult, hence in order to maintain the same, robotics plays a very important role in electrical system which will reduces time of maintenance. Considering worker's safety while working on OH line it will have good potential. On the basis of survey of workers, the robot will segregate the data and will directly transfers to control room. The robot traverses continuously on high voltage PL. In this technique, robot is equipped with voltage sensor used for measuring voltage, current sensor used for measuring current on TL. RF module for communication purpose. Visual Camera are installed in robot to capture the images and sent to the control area. This method is so advantageous in reducing cost, increasing efficiency and enhancing safety.

 

## II. TRANSMISSION LINE INSPECTION PROBLEMS

### A. Damage to the Conductors

The Aluminium Conductor Steel Reinforced (ACSR) are one of the most popular conductor types. The most important phenomenon that degrades such conductors is corrosion of aluminium strands. Pollutants and moisture in the form of aqueous solutions containing chloride ions, ingress into the interface between the steel and the aluminium strands and attack galvanizing protection of the steel. Corrosion of the galvanizing coat exposes steel and aluminium to each other and leads to galvanic corrosion between iron and aluminium. As an anode, aluminium corrodes rapidly and white powder aluminium hydroxide is produced. Loss of aluminium strands decreases current carrying capacity and mechanical strength of the line.

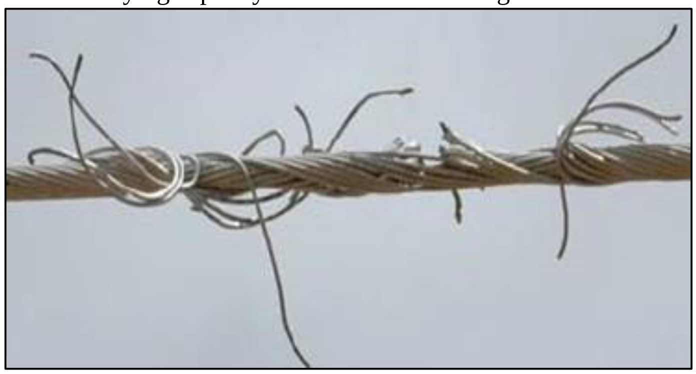

Fig. 1: Damaged conductors

In addition to corrosion, wind induced vibrations can make severe mechanical damage to the conductors due to generating cyclic mechanical load. The wind flow creates vortices downstream when it passes the line. These vortices produce fluctuating lift and drag force causing vibrations with frequencies from 1030 Hz and amplitudes of the order of diameter of the conductor. In bundled conductors, the wind also induces sub-conductor's oscillations, which can cause fretting of the aluminium strands near the clamps. The fretting reduces the fatigue strength of the line and speeds up the failure process.

### B. Damage to the Insulators

The insulators are affected by impact weathering, cyclic mechanical and thermal loading, ionic motion, cement growth and corrosion. Temperature difference between hot sunny days and freezing cold nights as well as the heats generated by fault current arcs cause thermal cycling, which produce micro- cracks and allows water to penetrate into material. The amount of imposed stress depends on relative expansibility of dielectric, metal fittings and the cement used to fix the metal fittings of the line to the dielectric. Cement growth which is mainly caused by delayed hydration of periclase (Mgo) as well sulphate related expansion, generates radial cracks in the porcelain insulators shell and makes them faulty. Contaminants in the atmosphere, such as sea or roads salts, can attack both Portland cement itself or it penetrates into metal parts, can corrode galvanizing surface. Ionic motion caused by electric field makes this situation worse.

Fig. 2: Damaged insulators

### C. Failing Compression Splice

Some equipment is notoriously difficult to inspect. An example is a compression splice running risk of failure. When two lengths of conductor are connected, a compression splice is used to hold them together. Compression splices sometimes fail. However, when they do it must be quickly repaired or the whole line might fail. The resistance over a compression splice in good condition is lower than that over regular conductor of equal length. When the compression splice is failing this resistance is increased. The increased resistance result in heat in the splice, and the status of the splice deteriorates even further in a downward spiral. The current way to detect this is to either measure the resistance over the splice or to measure the temperature of the splice. Both are tricky things to do, considering the splice is on extreme voltage potential, high over ground and more often than not subject to winds that cool any temperature differences down to the immeasurable.

Fig. 3: Replacement of failed splice

### *D. Corona Discharges*

A corona discharge is “an electrical discharge brought on by the ionization of a fluid surrounding a conductor, which occurs when the potential gradient exceeds a certain value, in situations where sparking (also known as arcing) is not favoured”. In the context of power line (PL), corona formation is considered a very bad thing as it results in radio interference, ozone formation and equipment fatigue. Corona discharges are further associated with strange sounds and can even be visible at night time, resulting in public concern over PL safety. Equipment designed for operation on live PLs needs to take this into account. Otherwise, functionally identical parts might cause or not cause corona discharges depending on the shape of extending edges. Smooth and round edges generally cause less corona issues. Another cause of corona discharge formation is faulty equipment. Corona inspection has been the target of recent product development. Combining images from several camera types using advanced algorithms, it is possible to spot corona discharges in daylight. Cameras capable of this are available for purchase. These cameras are used by a spotter on a helicopter or airplane.

Fig. 4: Corona on failing porcelain insulator

## III. EXISTING POWER LINE PROBLEMS

### *A. Initial Inspection*

After the construction, TLs are inspected and this is known as initial inspection. Linemen or wiremen should climb each structure and check the following while inspecting a TL; conductor condition, conductor sag and clearance to ground, trees and structures, insulator conditions, structure vibration and alignment, ground-wire connections and conditions, ground resistance at each structure, structure footings, obstruction light operations for aircraft warning.

### *B. Ground Inspection or Manual Inspection*

Ground inspection is the oldest PL inspection method. A crew of service personnel is sent out on the mission to inspect a PL. The personnel carry equipment to aid them in their task, but ultimately rely on their senses to perform the inspection. In places with heavy snow-fall, snowmobiles can be used. If no similarly convenient option is available, the service personnel have to traverse the length of the PL on foot. In order to inspect the lines, workers must walk on the lines, in many cases suspended 100m above the ground. Special gondolas may also be employed, allowing the operator to slide on the cables. These methods imply the interruption of transmission of electricity, require skilled workers, and expose the workers to unnecessary levels of danger and stress. Once under the PL, the service personnel must assess the status of it.

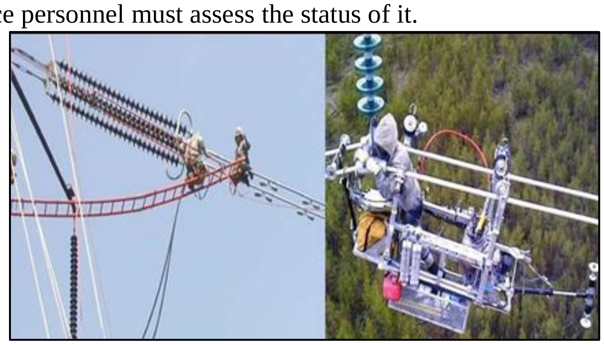

Fig. 5: Service personnel working on energized lines

The primary method of doing this is to visually asses the structures, using binoculars, cameras, or plain eyesight. Visual assessment is sufficient for most inspection of vegetation, insulators, towers and cables. Certain PL faults, such as corona discharges, result in characteristic sounds. In these cases, the ground crew can listen for the presence or absence of a fault. An antenna can be used to detect corona discharges, as they cause radio interference. Infrared cameras or other sensors capable of remotely sensing temperature are used to find other faults, such as failing compression splice. At times, the service personnel performing the ground inspection need to climb towers or even mount the actual line. Examples of this can be seen in Fig 6. disadvantages of ground or manual inspection includes requires skilled labours, long inspection cycle, high working intensity, high risk, have to switch off the supply when worker climbs on the line, costlier method.

### *C. Aerial Inspection*

Airborne surveillance is the next logical step after ground inspection. If visual surveillance does not satisfy inspection needs, then a fly-over will be much more efficient than traversing the PL on foot. Airborne inspection is performed from helicopter or aircraft. One option to this method is to carry out visual inspection of the cables by helicopter with video cameras. However, these inspection tasks tend to be expensive, and often provide just partial images of the cables. Flying helicopters close to the TLs and towers also involves risks that should be avoided. Some of these risks may be reduced by employing unmanned helicopters. Visual inspection from the ground is sometimes performed, but with very limited results. As alternatives to visual inspection, thermal sensing, X-ray and electric sensing can be used to detect damages in the TLs, but the sensors need to be positioned very close to the cables.

### *D. Helicopter Inspection*

Helicopter inspection is performed much the same way as airplane inspection, with one pilot and one or possibly more spotters; see Fig- 4.3. Pilots fly close over the line while an inspector, called spotter, sit next to them looking down at the line. Sometimes more than one spotter is used to look at different features of the equipment. The use of helicopters and airplanes for inspection differs somewhat, as helicopters are much less fuel efficient and come with a higher maintenance tag.

Fig. 6: Helicopter inspection of PL

Helicopters are used when their ability to hover is needed. Typically, this is when inspecting smaller lines or PLs in populated areas. When inspecting long stretches of high voltage PLs, airplanes are preferred. One exception where helicopters are used on high voltage lines is in fault location. When a fault has brought a PL out of service, helicopters are used to locate the fault. The cause of a fault is often a tree or forestry equipment in contact with the conductor. Disadvantages of aerial inspection includes, very expensive, not safe, decreases efficiency, video images provided from helicopter will be out of focus, takes long time for inspection, requires skilled labours.

## IV. LINE INSPECTION ROBOT

The robot forming the core of the line inspection robot mobile sensor system must comply with several demands for the system to be useful. The robot must travel along the conductor of a high voltage PL, pass pre-defined obstacles on the PL (i.e. all common obstacles), capture enough power for robot's use from the magnetic field generated by the conductor (possibly storing power for intermittent operation), inspect pre-defined features on the PL, communicate with a base station (or other unit of similar function). The line inspection robot will be part of a system offering the inspection capability.

The system must at least have the ability to conveniently raise the robot to and lower it from the line to be inspected and provide some initial analysis of the results of an inspection offering some way of communication with the operating robot and the control room. The operating conditions close to a live conductor of a high voltage PL are extreme. The line inspection robot may not cause harm to people or equipment, specifically; it must not damage the conductor on which it travels, it must not cause damage to insulators, it must not cause flashovers between tower and conductor, it must not cause flashovers between different phases, it must not cause corona discharge.

Fig. 7: Line inspection robot

We have established temporary HT towers with the TLs of ACSR type. The robot is placed on ACSR conductors; the robot will be mount on transmission line by the support of nylon wheels. A controller board and the GPRS modem is used for data connection. This method is used only for data collection at sending and receiving end. The robot is used for data collection at fault location from live line. Basically the robot consists of a current coil for the purpose of measurement of insulation strength, 12V dc supply operated motors, composite type robot frames, thermal imaging camera, rotating gears & rotating shaft, micro-wheel assembly, transmitter, receiver, GPS and a micro-controller unit. Current coil is placed to determine the flow of current factor through the live TLs and the change in the current coil reading gives the quality of insulation. It is also used to determine the transmission voltage level.

Fig. 8: Robot installation using rope

Thermal imaging camera is used to measure the temperature of components & also for identification of any obstacles at the time of forward reverse movement of robot system, this captured image will directly send through transmitter & receiver to the control room by using GPS software. The robot will be placed on transmission line by switching on its control supply which is being taken from 12V DC battery. On ACSR TL suppose high current flows through lines, current coils will measure the current flowed through the lines. By same method the voltage will be measured by voltage transformer. Referring to received current from current transformer (CT) we can conclude that system is healthy or not healthy which will be displayed on the LCD display mounted on robot system. By this method we can take the live pictures which will show us on line images & any obstacles may hamper the life of transmission n lines. Same information's are transferred to control rooms using GPS software's, RF transmitter & receiver. When the robot encounters an obstacle on its path, it matches it to six-bit code to which a motion sequence can be associated. The grippers on the wheel provides a grasp on both the sides of the obstacles. A motor current watchdog is implemented to detect any abnormalities and to immobilize the unit until the situation could be analysed by an operator.

## V. OBSTACLES ON TRANSMISSION LINE

### *A. Insulator*

An insulator attaches the conductor to a tower or other structure. When climbing around this type of obstacle it is vital not to protrude too much from the live line. Unless the extending part is entirely shielded and does not conduct electricity, it might cause flashover between live line and grounded structure. In the majority of TL it is safe to extend below the line while climbing, but there are unfortunately many cases where this is not true and where it is better to extend to the sides.

Fig. 9: Insulator

### *B. Bundle Conductors with Spacers*

High voltage PLs with single conductors implicitly have extreme electrical fields close to the conductor. The high electric fields focus at protrusions from the conductor and if strong enough form a corona. Using multiple bundled conductors separated by spacers is one common way of alleviating corona issues. Bundled conductors dilute the electric field to the point where no coronas form. In the Swedish transmission grid maintained by some 15000 km of 220 kV and 400 kV PLs, twin or triple bundled conductors is used without exception.

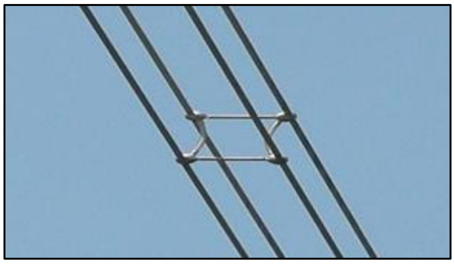

Fig. 10: Bundled conductors

Spacers on a bundled conductor occur much more frequently than towers and other obstacles on non-bundled conductors, so a robot designed to operate on a bundled conductor must be very good at navigating around these obstacles. As obstacles, spacers are frequent but not critically difficult as they generally occur in areas where there are no other phases or grounded structures in close vicinity of the obstacle. There are of course, exceptions to this as to everything and spacers on bundled lines occurring on the loop in a tension clamp (covered below) might pose quite a challenge to climb around.

### *C. Vibration Dampers*

Vibration dampers are placed on conductors to minimize the effects of wind induced vibrations. The number of dampers varies between 0 and 4 per span of PL between two towers (0-4 per phase line). Dampers are placed 0.8 m or 1.5 m measured from the centre of the suspension clamp to the centre of damper clamp. Vibration dampers occur sometimes in pairs and relatively close to towers. Thus they add to the difficulty of passing obstacles on the conductor. If obstacles occurred one on one separated by a length of empty wire, a method to climb around obstacles could be used that relied on this empty space. As it is, any method of clearing obstacles must take into account that the target stretch of conductor after an obstacle might be short.

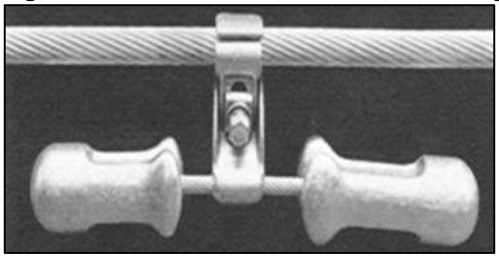

Fig. 11: Vibration dampers

### *D. Tension Clamp*

Tension clamps as can likely be deduced from the name, adds tension to the conductor. In a long stretch of straight PL, about every tenth tower will carry tension clamps. In mountainous areas, this ratio might be different. A tension clamp consists of two insulators adding tension to the conductor spans extending from the tower. Below the insulators, the conductor extends in a loop below the tower. Sometimes the conductor loop is held down by weights or insulators to keep it out of harm way. As an obstacle, a tension clamp is a formidable challenge and one that must be conquered. The loop of the tension clamp is not under any tension and thus any technique for clearing obstacles relying on wire tension will run into difficulties here. The loop also descends almost vertically from the mouth of the tension clam so the mechanism gripping the conductor must accommodate for this. A further difficulty is the potentially close proximity of grounded structures. Different phases might also pass close to each other in some vertically arranged towers with tension clamps.

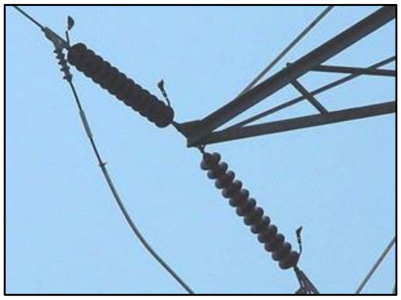

Fig. 12: Tension clamp

## VI. BLOCK DIAGRAM OF ROBOT INSPECTION

### *A. Transmission Block*

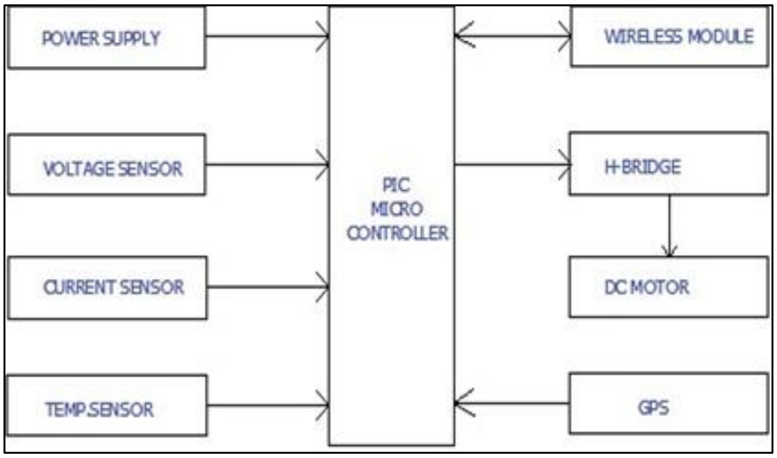


Fig. 13: Transmission Block

The images that are captured from the camera are received by the controller. Once the images are received they have to be compared. At first the images are processed by digital image processing then the unwanted noises are removed. Then the images are authenticated and recognized. The original images are saved in the monitoring section. When the captured images are received they are compared. The self-governing on robot's obstacle overcoming is realized by means of autonomous navigation of multiple electromagnetic sensors and machine visual hybrid servo.

### *B. Block Diagram of Monitoring System*

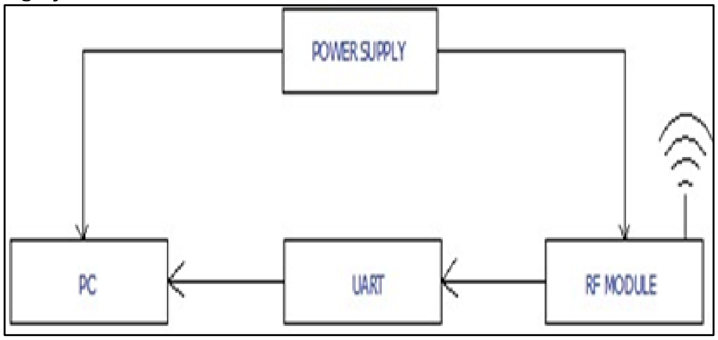


Fig. 14: Monitoring section

The images on transmission line and surrounding area captured from the camera are received by the controller through the RF module. The images of transmission line conditions are observed on our PC in a control room. In case if any defects found then Red LED glows and LCD indicates transmission line faulty.

## VII. CONCLUSION AND SCOPE FOR FUTURE WORK

Considering above details conclude that by using robot for maintenance of transmission line we can reduce the time which will affect the other system at the time of maintenance. Also important is the life of human being, avoids hap hazardous considering to safety point & reliability of system. To carry servicing of transmission line it will be helpful in future use of robot. This system works on automatic system by remote control system using RF transmitter & receiver by sending images & videos. The major advantages include: utilization of man are minimizing, captures images of TL & surrounding areas, rolls on entire day with 1m/s speed, do live line work and ensure safety, both save money & time, can accommodate new devices. Tightens, loosen bolts & repair broken cable strands.

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