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Line inspection robot

[1] Guru Prasad K, [2] Bala Chandra Mouli B, [3] Sravan Kumar B, [4] Durga Rao CH, [5] Raja Sekhar G, [6] Sunil Kumar Jena

[1, 2, 3, 4, 5] Department of Mechanical Engineering VITS College of Engineering Anandapuram, Sontyam, Visakhapatnam, Andhra Pradesh, India

[6] Asst. professor, Department of Mechanical Engineering VITS College of Engineering Anandapuram, Sontyam, Visakhapatnam, Andhra Pradesh, India

Abstract

This paper describes the development of a mobile robot capable of clearing such obstacles as counter weights, anchor clamps and torsion tower. The mobile robot walks on overhead ground wires on power tower. Its ultimate purpose is to automate to inspect the defect of power transmission line. We are trailing the use of transmission line inspection robot to help detect damage to transmission line conductors and associate fittings. The remotely piloted aerial vehicle would provide a high level of analysis and clear view of damage. Its ultimate purpose is to inspect the defect of transmission line. The robot consists of 6 motors, 4 wheels and arm. Visible light camera is also used to obtain video information. A prototype robot was developed with careful consideration of mobility. Results experiments demonstrate that the robot can be applied to execute the navigation and inspection tasks.

Keywords: mobile robot, DC motor, Brush motor, commutator

Introduction

This pre study report presents the results of a thesis work. In the thesis work the line inspection robot, a potential robotic solution to the power line inspection problem, was explored and developed. First the problem of power line inspection is expanded and defined. This is followed by a look at current techniques for solving the problem and a quick look at the proposed novel method of the line inspection robot. The last section of this report focuses on the actual line inspection robot, its principle of operation and its mechanical design Here is also presented a quick look at the future of the project and detailed requirement specification for the first prototype Power lines are everywhere. Over the past hundred years, electricity has become a part of our daily life and something mostnofn us take for granted. To supply us with electricity there is a need for well-developed power infrastructure. Electric power needs to be generated transmitted and distributed. Much of the power infrastructure is now nearing its end of life. In places structures originally built in the 1920's and 1930's are still in operation. Power transmission equipment and apparatus is generally counted as having an active service life of 50 years. Power transmission lines are usually inspected manually by workers riding in gondolas that travel suspended from the transmission lines or watching with telescope in the ground. In recent years it has become increasingly necessary to perform inspection work with autonomous inspection robot in power transmission line. The robot has 4 wheels and 6 dc motors and one robotic arm which was driven by spur and Worm gear mechanism. The ageing power infrastructure needs both continual maintenance and renewal. Transmission system operators (TSO) typically spend more time on renewing the transmission grid than they spend on the maintenance of it [1]. Renewal means that a whole line, or sections of it, is taken down for raw material reuse and new equipment is installed in its place. Maintenance is all activities which aim at prolonging the active life and good condition of equipment.

DC motor

A DC motor relies on the facts that like magnet poles repel and unlike magnetic poles attract each other. A coil of wire with a current running through it generates an electromagnetic field aligned with the centre of the coil. By switching the current on or off in a coil its magnet field can be switched on or off or by switching the direction of the current in the coil the direction of the generated magnetic field can be switched 180°. A simple *DC motor* typically has a stationary set of magnets in the stator and an armature with a series of two or more windings of wire wrapped in insulated stack slots around iron pole pieces (called stack teeth) with the ends of the wires terminating on a commutator. The armature includes the mounting bearings that keep it in the centre of the motor and the power shaft of the motor and the commutator connections. The winding in the armature continues to loop all the way around the armature and uses either single or parallel conductors (wires), and can circle several times around the stack teeth. The total amount of current sent to the coil, the coil's size and what it's wrapped around dictate the strength of the electromagnetic field created. The sequence of turning a particular coil on or off dictates what direction the effective electromagnetic fields are pointed. By turning on and off coils in sequence a rotating magnetic field can be created. These rotating magnetic fields interact with the magnetic fields of the magnets (permanent or electromagnets) in the stationary part of the motor (stator) to create a force on the armature which causes it to rotate. In some DC motor designs the stator fields use electromagnets to create their magnetic fields which allow greater control over the motor. At high power levels, DC motors are almost always cooled using forced air.

The commutator allows each armature coil to be activated in turn. The current in the coil is typically supplied via two brushes that make moving contact with the commutator. Now, some brushless DC motors have electronics that switch the DC current to each coil on and off and have no brushes to wear out or create sparks.

Fig 1: DC motor

Different number of stator and armature fields as well as how they are connected provide different inherent speed/torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems which adjust the voltage by "chopping" the DC current into on and off cycles which have an effective lower voltage.
Since the series-wound DC motor develops its highest torque at low speed, it is often used in traction applications such as electric locomotives, and trams. The DC motor was the mainstay of electric traction drives on both electric and diesel-electric locomotives, street-cars/trams and diesel electric drilling rigs for many years. The introduction of DC motors and a grid system to run machinery starting in the 1870s started a new second Industrial Revolution. DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles and today's hybrid cars and electric cars as well as driving a host of cordless tools. Today DC motors are still found in applications as small as toys and disk drives, or in large sizes to operate steel rolling mills and paper machines.
If external power is applied to a DC motor it acts as a DC generator, a dynamo. This feature is used to slow down and recharge batteries on hybrid car and electric cars or to return electricity back to the electric grid used on a street car or electric powered train line when they slow down. This process is called regenerative braking on hybrid and electric cars. In diesel electric locomotives they also use their DC motors as generators to slow down but dissipate the energy in resistor stacks. Newer designs are adding large battery packs to recapture some of this energy.

a) Brush
A brushed DC electric motor generating torque from DC power supply by using an internal mechanical commutation. Stationary permanent magnets form the stator field. Torque is produced by the principle that any current- carrying conductor placed within an external magnetic field experiences a force, known as Lorentz force. In a motor, the magnitude of this Lorentz force (a vector represented by the green arrow), and thus the output torque is a function for rotor angle, leading to a phenomenon known as torque ripple) Since this is a single phase two-pole motor, the commutator consists of a split ring, so that the current reverses each half turn (180 degrees).

Fig 2: Brush motor

Advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses. Maintenance involves regularly replacing the carbon brushes and springs which carry the electric current, as well as cleaning or replacing the commutator. These components are necessary for transferring electrical power from outside the motor to the spinning wire windings of the rotor inside the motor. Brushes consist of conductors.

b) Brushless
Typical brushless DC motors use a rotating permanent magnet in the rotor, and stationary electrical current/coil magnets on the motor housing for the stator, but the symmetrical opposite is also possible. A motor controller converts DC to AC. This design is simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor.

Fig 3: Brushless motor

Advantages of brushless motors include long life span, little or no maintenance, and high efficiency. Disadvantages include high initial cost, and more complicated motor speed controllers. Some such brushless motors are sometimes referred to as "synchronous motors" although they have no external power supply to be synchronized with, as would be the case with normal AC synchronous motors.

Uncommutated
Other types of DC motors require no commutation.

- **Homopolar motor:** A homopolar motor has a magnetic field along the axis of rotation and an electric current that at some point is not parallel to the magnetic field. The name homopolar refers to the absence of polarity change. Homopolar motors necessarily have a single-turn coil, which limits them to very low voltages. This has restricted the practical application of this type of motor.
- **Ball bearing motor:** A ball bearing motor is an unusual electric motor that consists of two ball bearing- type

bearings, with the inner races mounted on a common conductive shaft, and the outer races connected to a high current, low voltage power supply. An alternative construction fits the outer races inside a metal tube, while the inner races are mounted on a shaft with a non-conductive section (e.g. two sleeves on an insulating rod). This method has the advantage that the tube will act as a flywheel. The direction of rotation is determined by the initial spin which is usually required to get it going.

Permanent magnet stators

A PM motor does not have a field winding on the stator frame, instead relying on PMs to provide the magnetic field against which the rotor field interacts to produce torque. Compensating windings in series with the armature may be used on large motors to improve commutation under load. Because this field is fixed, it cannot be adjusted for speed control. PM Fields (stators) are convenient in miniature motors to eliminate the power consumption of the field winding. Larger DC motors are of the "dynamo" type, which have stator windings. Historically, PMs could not be made to retain high flux if they were disassembled; field windings were more practical to obtain the needed amount of flux. However, large PMs are costly, as well as dangerous and difficult to assemble; this favors wound fields for large machines.

Fig 4: Permanent magnet stator

To minimize overall weight and size, miniature PM motors may use high energy magnets made with neodymium or other strategic elements; most such are neodymium-iron-boron alloy. With their higher flux density, electric machines with high-energy PMs are at least competitive with all optimally designed singly fed synchronous and induction electric machines.

Wound stators

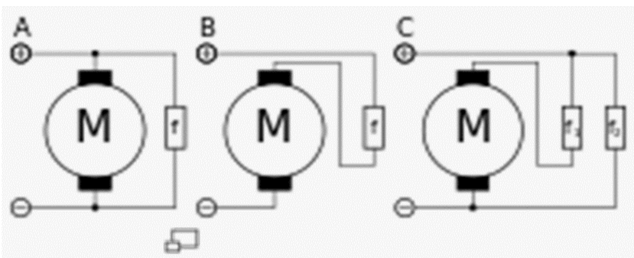


Fig 5: Wound stator

A field coil may be connected in shunt, in series, or in compound with the armature of a DC machine (motor or generator)

There are three types of electrical connections between the stator and rotor possible for DC electric motors: series, shunt / parallel and compound (various blends of series and shunt/parallel) and each has unique speed/torque characteristics appropriate for different loading torque profiles / signatures.

i) Series connection

A series DC motor connects the armature and field windings in series with a common D.C. power source. The motor speed varies as a non-linear function of load torque and armature current; current is common to both the stator and rotor yielding current squared (I^2) behavior. A series motor has very high starting torque and is commonly used for starting high inertia loads, such as trains, elevators or hoists [2]. This speed/torque characteristic is useful in applications such as dragline excavators, where the digging tool moves rapidly when unloaded but slowly when carrying a heavy load. With no mechanical load on the series motor, the current is low, the counter-EMF produced by the field winding is weak, and so the armature must turn faster to produce sufficient counter-EMF to balance the supply voltage. The motor can be damaged by over speed. This is called a runaway condition.

Series motors called "universal motors" can be used on alternating current. Since the armature voltage and the field direction reverse at (substantially) the same time, torque continues to be produced in the same direction. Since the speed is not related to the line frequency, universal motors can develop higher-than-synchronous speeds, making them lighter than induction motors of the same rated mechanical output. This is a valuable characteristic for hand-held power tools. Universal motors for commercial power frequency are usually small, not more than about 1 kW output. However, much larger universal motors were used for electric locomotives, fed by special low-frequency traction power networks to avoid problems with commutation under heavy and varying loads.

ii) Shunt connection

A shunt DC motor connects the armature and field windings in parallel or shunt with a common D.C. power source. This type of motor has good speed regulation even as the load varies, but does not have the starting torque of a series DC motor [3]. It is typically used for industrial, adjustable speed applications, such as machine tools, winding/unwinding machines and tensioners.

iii) Compound connection

A compound DC motor connects the armature and fields windings in a shunt and a series combination to give it characteristics of both a shunt and a series DC motor [4]. This motor is used when both a high starting torque and good speed regulation is needed. The motor can be connected in two arrangements: cumulatively or differentially. Cumulative compound motors connect the series field to aid the shunt field, which provides higher starting torque but less speed regulation. Differential compound DC motors have good speed regulation and are typically operated at constant speed.

Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays.

Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.
A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".
A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts (there are two in the relay pictured). The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. It is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit.
In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open. Other relays may have more or fewer sets of contacts depending on their function. The relay in the picture also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the printed circuit board (PCB) via the yoke, which is soldered to the PCB.
When an electric current is passed through the coil it generates a magnetic field that activates the armature, and the consequent movement of the movable contact(s) either makes or breaks (depending upon construction) a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the

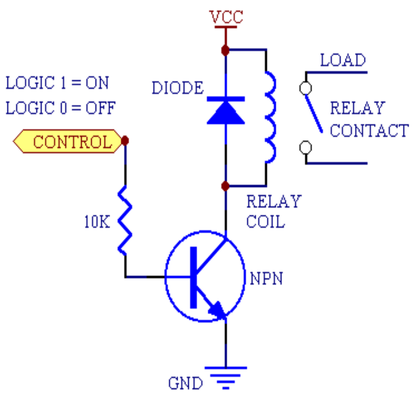


Fig 7. Operation of relay

coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low-voltage application this reduces noise; in a high voltage or current application it reduces arcing.

When the coil is energized with direct current
A diode is often placed across the coil to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to semiconductor circuit components. Some automotive relays include a diode inside the relay case. Alternatively, a contact protection network consisting of a capacitor and resistor in series (snubber circuit) may absorb the surge. If the coil is designed to be energized with alternating current (AC), a small copper "shading ring" can be crimped to the end of the solenoid, creating a small out-of-phase current which increases the minimum pull on the armature during the AC cycle.
In the robots I used about 16 channel relay to drive motor clock and anti-clock direction shows in the below diagram.

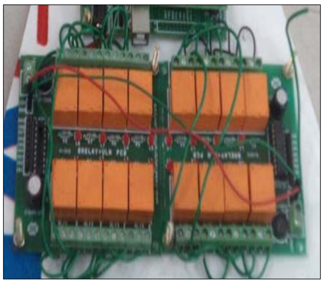


Fig 8. Connection of relay

In the above figure the relay is having 5 terminal each. In that each relay will have normally open (NO) and normally closed (NC).
All NO pins are connected each other, similarly NC pins have the same connection, when microcontroller drives it the relay will ionize and opens the motor to drive.

Literature review
"Intelligent Autonomous Systems: Foundations and Applications" by Dilip Kumar Pratihar, Lakhmi C. Jain. Intelligent Autonomous Systems (IAS) are the physical embodiment of machine intelligence providing a core concept for integrating various advanced technologies with pattern recognition and learning. The basic philosophy of IAS research is to explore and understand the nature of intelligence in problems of perception, reasoning, learning and control in order to develop and implement the theory to engineered realization. In other words, the objective is to formulate various methodologies for the development of robots which can operate autonomously and exhibit intelligent behavior by making appropriate decisions to perform the right task at the right time. Since IAS basically deals with the integration of machines, computing, sensing, and software to create intelligent systems capable of interaing with the complexities of the real world, advanced topics like soft computing, artificial life, evolutionary biology, and cognitive psychology have great promise in improving its intelligence and performance. Because of the inter-disciplinary character, the subject has several challenging issues for research, design and development covering a number of disciplines. These issues are further concerned with the development of both technology

and methodology apart from various operations. The present research monograph titled “Intelligent Autonomous Systems: Foundations and Applications", edited by two renowned researchers, Professor Dilip K. Pratihar of IIT, Kharagpur, India and Professor Lakhmi C. Jain, University of South Australia, Australia, provides a fairly representative cross-section of the activities that is going on all over the world in this area.

Robot Motion and Control by Krzysztof Kozłowski

Robot Motion Control 2011 presents very recent results in robot motion and control. Forty short papers have been chosen from those presented at the sixth International Workshop on Robot Motion and Control held in Poland in June 2011. The authors of these papers have been carefully selected and represent leading institutions in this field. The following recent developments are discussed: Design of trajectory planning schemes for holonomic and nonholonomic systems with optimization of energy, torque limitations and other factors. New control algorithms for industrial robots, nonholonomic systems and legged robots. Different applications of robotic systems in industry and everyday life, like medicine, education, entertainment and others. Multiagent systems consisting of mobile and flying robots with their applications The book is suitable for graduate students of automation and robotics, informatics and management, mechatronics, electronics and production engineering systems as well as scientists and researchers working in these fields.

Leonardo da vinci created many robot like sketches and designs in the 1500’s.The word robot first appeared in print in the 1920 play R.U.R. (Rossum’s Universal Robots) by Karl Kapek, a Czechoslovakian playwright. Robota is Czechoslovakian for worker or serf (peasant). Typical of early science fiction, the robots take over and exterminate the human race. Isaac Asimov popularized the term robotics through many science-fiction novels and short stories.

Asimov is a visionary who envisioned in the 1930’s the Positronic brain for controlling robots; this pre –dated digital computers by a couple of decades. Unlike earlier robots in science fiction, robots do not threaten humans since Asimov invented the three laws of robotics:

1. A robot may not harm a human or, through inaction, allow a human to come to harm.
2. A robot must obey the orders given by human beings, except when such orders conflict with the First Law.
3. A robot must protect its own existence as long as it does not conflict with the First or Second Laws.

Joseph Engleberger and George Devoewere the fathers of industrial robots. Their company, animation, built the first industrial robot, the PUMA (PROGRAMMABLE UNIVERSAL ANIPULATORM)

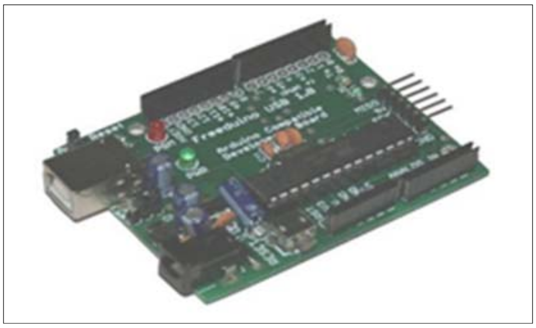
Arduino

Any microcontroller based board which follows the standard Arduino schematic and is flashed with the Arduino boot loader can be called an Arduino board. The Arduino is referred to as open source hardware, since the standard schematic is open to everyone and anybody can make their own version of Arduino board following the standard schematic.

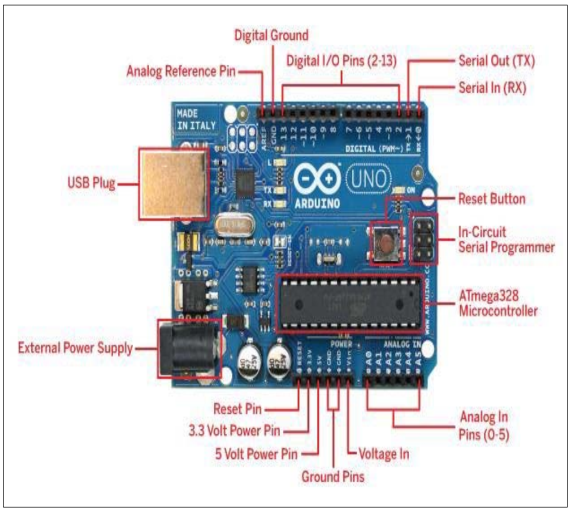
Arduino is a single board microcontroller, intended to make the application of interactive objects or environments more accessible. The hardware consists of an open source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. Pre- programmed into the on-board microcontroller chip is a boot-loader that allows uploading programs into the microcontroller memory without needing a chip /device programmer.

Arduino started in 2005 as a project for students at the Interaction Design Institute Ivrea in Italy. The core Arduino developer team is composed of Massimo Banzi, David Cuartielles, and David Mellis. Arduino family consists of UNO, LILYPAD, DIECIMILA, NANO, and DUEMILANOVE.

Arduino Board



Pin description



Straight Forwards

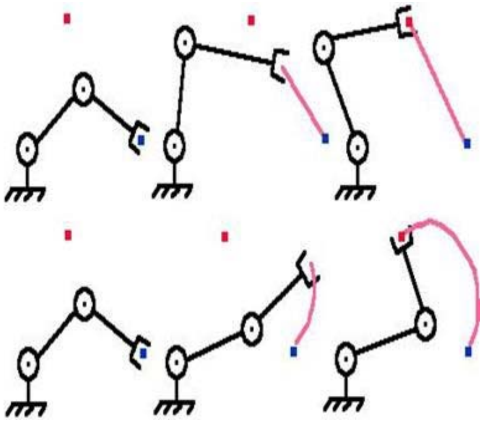
Both wheels rotate at the same speed, but the right wheel rotates forward and the left wheel rotates backward, so the robot turns to its left around its center. This makes a sharp turn in place.

Straight forward

Straight Backwards
Both wheels rotate forward at the same speed and the robot moves straight backward.

Straight backward

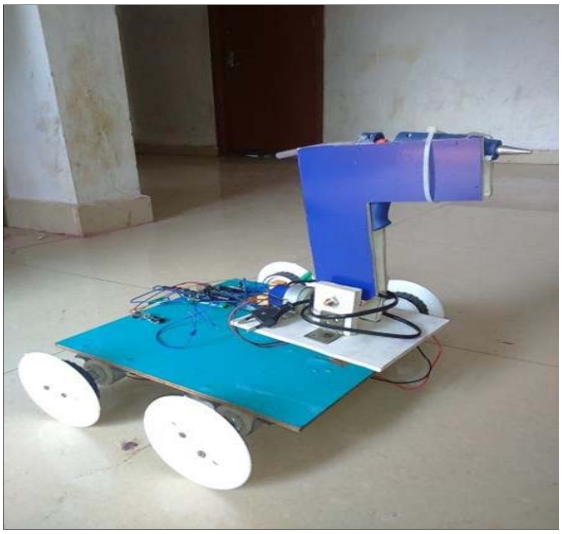
Arm Movement
The degrees of freedom, or DOF, are a very important term to understand. Each degree of freedom is a joint on the arm, a place where it can bend or rotate or translate. We can typically identify the number of degrees of freedom by the number of actuators on the robot arm. Now this is very important - when building a robot arm we want as few degrees of freedom allowed for our application, Because each degree requires a motor, often an encoder, and exponentially complicated algorithms and cost.



Arm Movement

Power supply
This is a circuit which supplies the necessary voltages to all the circuits and systems on the vehicle. The power source will be a 12V PP3 Battery. The 2 volt ―rails‖ initially planned are 12V and 1.2Ah to drive the motors, and 12V to drive the low power and logic circuitry. The Battery is low soon.

a) Mechanism of a Robot
The automatic line inspection robot consists of an adjustable wooden frame, D.C motors, Wheels, On-Off Switch, Connecting wires, circuit board and a platform has briefly described some of the inspection and maintenance work performed on the live transmission lines. These inspections help maintain a service continuity while performing tasks that would have required working on de-energized lines. The future of transmission line robotics is likely to grow through collaboration among power utilities. This future includes high-voltage applications such as detection of corrosion of the steel core ASCR conductors and broken inner layer of standards, often located beneath a hardware clamp. As robotic technologies enter the systematic inspection programs of utilities, it is reasonable to foresee that they acquire greater autonomy eventually allowing not only autonomous crossing of obstacles, but also detection and identification of potentially defective components.



Conclusion
This pre-study report has described the power line inspection robot .The report has also presented and analyzed a novel solution to it: the line inspection robot.
If the line inspection robot is to work, it needs to master five key technologies:

- Climb on energized line
- Pass obstacles
- Inspect equipment
- Autonomous operation
- Gather power from line

These five technologies are all vital to the completed line inspection robot. The technologies were analyzed for relevance in a first, simplified prototype. The decision was made to focus on the second item: passing obstacles. The reason behind this decision is that climbing past obstacles is the most difficult to achieve and at the same time only really novel technology. Passing obstacles is the sine equ non of the line inspection robot.

The report presented previous solutions to the problem, and then went on to describe the solution developed for the new line inspection robot. Focus was placed on mechanical design and many details were given on individual design and their motivation

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