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# FAULT DETECTION AND LOCATION IN TRANSMISSION LINES USING POLE CLIMBING ROBOT

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## ABSTRACT
Reliable electric power supply with minimised failures is the key factor that the present society is keenly looking for. Higher voltages and supporting devices are being devised for better power transmission. But the still followed manual inspection of overhead lines throws light on the fact that these tasks are tedious, expensive, time consuming and extremely dangerous and the hazard of those people working on the fault detection and rectificaton is still at large . So as a noval life saving project, research focussed on automating the inspection by mobile robots which surpasses the above mentioned disadvantages. The mobile robot proposed in this paper is an RF remote controlled one with mainly three instructions of start, stop and reverse. The VSWR method chosen for fault location provides with the actual positioning of fault along the transmission line.

**KEYWORDS**: Degree Of Freedom (DOF), Fault Detection, LiPo, Robotics, VSWR.

## INTRODUCTION
A robot is a mechanical or virtual artificial agent, usually an electro-mechanical machine that is guided by a computer program or electronic circuitry. Robots have replaced humans in the assistance of performing those repetitive and dangerous tasks which humans prefer not to do, or are unable to do due to size limitations.
Crisis conditions such as natural catastrophes, chemical contamination or riots require a precise, fast and reliable estimation of the situation all along the crisis. The collected data can be provided by cameras or any type of suitable sensor. They are generally collected from different observation points and are then centralized to the coordination center. Observation data from an elevated point of view could bring a significant advantage, particularly in urban landscape, where many obstacles prevent direct vision. The preferred solution presented here is a climbing robot that is capable to bring, with minimum energy, sensors and communication devices on top of common elevated urban structures such as poles, lamp posts.
Here in this project a new type of pole-climbing Robot mechanism is proposed, the configuration and characteristics of the mechanism are introduced. The mechanism of the robot has the characteristics of compact body, easy control, good move characteristics, and is a promising application of pole climbing robot structure. Our prototype of "Pole climbing Robot" has the capability to climb over the poles and perform the desired task smoothly. Robot is designed to climb as well as to descent. The robot is intended for upward and downward movement. H bridge is used to control the rotation of motor used for the climbing purpose of robot. Robot is controlled by the remote control with three commands start, stop and reverse.
The fault detection mechanism integrated in the robot is that of VSWR. Standing waves of radio frequency is measured on the transmission line to detect the fault location of the line. Separate system for the measurement of voltage and current has been integrated with it.

## FAULT DETECTION USING VSWR METHOD
VSWR (Voltage Standing Wave Ratio), is a measure of how efficiently radio-frequency power is transmitted from a power source, through a transmission line, into a load (for example, from a power amplifier through a transmission line, to an antenna).

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In an ideal system, 100% of the energy is transmitted. This requires an exact match between the source impedance, the characteristic impedance of the transmission line and all its connectors, and the load's impedance. The signal's AC voltage will be the same from end to end since it runs through without interference.

In real systems, mismatched impedances cause some of the power to be reflected back toward the source (like an echo). Reflections cause destructive interference, leading to peaks and valleys in the voltage at various times and distances along the line.

VSWR measures these voltage variances. It is the ratio of the highest voltage anywhere along the transmission line to the lowest. Since the voltage doesn't vary in an ideal system, its VSWR is 1.0 (or, as commonly expressed, 1:1). When reflections occur, the voltages vary and VSWR is higher -- 1.2 (or 1.2:1), for instance.

Mathematically, VSWR is the voltage ratio of the signal on the transmission line:

$$VSWR = |V(max)| / |V(min)|$$

where V(max) is the maximum voltage of the signal along the line, and V(min) is the minimum voltage along the line.

It can also be derived from the impedances:

$$VSWR = (1+\Gamma)/(1-\Gamma)$$

where $\Gamma$(gamma) is the voltage reflection coefficient near the load, derived from the load impeadance (ZL) and the source impedance (Zo):

$$\Gamma = (ZL-Zo)/(ZL+Zo)$$

If the load and transmission line are matched, $\Gamma = 0$, and VSWR = 1.0 (or 1:1).

In general, VSWR may be determined from the voltage measured along a transmission line leading to an antenna. Thereby, VSWR is the ratio of the maximum amplitude of a standing wave to the minimum amplitude of a standing wave. In case an antenna is not matched to the transmitter, power is reflected, which causes a reflected voltage wave, creating standing waves along the transmission line. However, the on-site location of a VSWR fault requires disconnecting of the antenna line from the base transceiver station (BTS) and connecting of external measurement equipment to the antenna line and/or visual inspection.

In particular, the robot is an object of the present invention to provide a method, apparatus and computer program product for enabling improved distance to fault measurement for voltage standing wave ratio (VSWR) on antenna line in networks and transmission lines.

The method comprising of transmitting a signal to a line to be tested, capturing a forward signal of the signal, capturing a reverse signal of the signal, separating the reflection of the signal via cross correlation of the forward signal and the reverse signal, and detecting a distance to fault in the line by searching and processing of the captured and separated signals. The Microcontroller then accepts this signal, the program on the microcontroller is executed and it is configured to carry out the fault detection and location.

For the fault detection we use the principle of a time domain reflectometer. A Time Domain Reflectometer is used to not only find the location of a fault within a cable but it is also used to identify degrading cable conditions before specific problems develop.The TDR transmits a high-frequency pulse down the cable pair. If there are no impedance miss-matches on the cable pair, the screen will show a flat line with no reflections. Any impedance miss-match will cause all or some of the transmitted signal to be sent back towards the source.

We will be using the same principle here but in terms of capacitance. We will use the capacitive reactance to measure a voltage drop. An external capacitor of reactance $X_{c1}$ will be connected in series with the pair of cables whose reactance is $X_{c2}$. An input voltage is applied at the $X_{c1}$ side and the output voltage is measured across the transmission line capacitance.

$$V_{0} = X_{c1}.\, V_{in} / (X_{c1} + X_{c2})$$

Under normal working conditions since the input voltage is small the resisitive effect will be larger and hence the output voltage will be the same as the input voltage. But in case of a break the capacitive effect can no longer be ignored. Hence a voltage drop occurs across the transmission line. Voltage will be proportional to the capactive reactance of the transmission line and also the capacitance of the line will be proportional almost linearly to the distance. In standard time domain reflectometers this relation is taken as linear hence we will be taking the same linearity. Measurung the output voltage thus will give an idea of the length of the fault if we know the standard capacitance per unit length. For this we need to undergo experimental analysis to find the capacitance per unit length. For this we provide an artificial break at a particular know length and find its

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capacitance. This data is enough to find the length of the fault at any capacitance due to the linear relation of the capacitance and length. Now we use the experimental data as a standard and then measure the capacitances and calculate the length of the break. To perform this action on a live wire we use an optoisolator or optocoupler device to isolate the device from the live supply so that damage maybe avoided. The arms of the robot will provide the electrical contact to the transmission line. The data thus obtained is relayed onto the remote device that has a display that shows the calculated data.

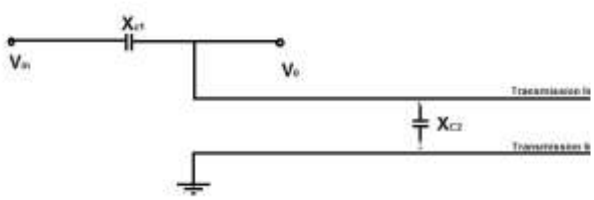

*Fig.1 Schematic diagram of a transmission line fault detection circuit.*

Since, the capacitance in a transmission line is considered to be a lumped parameter, the approximation of the fault location can be made more accurate by cheching and changing different values of capacitors for $X_{c1.}$

## PHYSICAL DESIGN OF ROBOT

The designing of the robot is done so as to ascend and descent along the pole with a degree of freedom 1. The total weight of robot is about 2.5 kg which is the sum of weight of motors, weight of battery, weight of skeleton and weight of circuit. Lithium Polymer Battery abbreviated as LiPo of 11V acts as the source of power for the whole system. The 4 arms are fixed with the actuators constituting the metal gear motors of 12V, 2400 rpm and is supposed to rotate at 10 rpm. The H Bridge is used to control the direction of the motors used for climbing purpose. Gripping mechanism is provided by the rubber tyres of 10 cm diameter for climbing the pole. The upper arms are mechanically connected with the tactile switch which gets pressed as the robot reaches its final destination and the arms touches the transmission line. Along with the tactile switch the upper arms are also provided with hall sensor ACS712 for the detection of current and voltage along the transmission line. The motion of the robot is controlled by RF remote control basically providing three main instructions of start, stop and reverse. The encoder continuously reads the status of the switches, passes the data to the RF transceiver and the transceiver transmits the data which is to be displayed on the LCD provided on the remote.

## CONCEPTUAL SYSTEM DESSIGN

The whole system can be divided into two parts. The robot which climbs the pole and the remote control that control the ascend and descent of the robot along the pole. The robot also consists of the fault detection and location circuitry. The data corresponding to the fault are all colleceted and processed at the robot section and it is send then to the remote part for the display purpose only.

The major design considerations and system requirements of the robot are:

1) The motion of the robot is along a vertical plane and not in a flat plane.
2) Moving plane is flat. There is nothing for the robot to clip or hang onto.
3) Be stable and not to flip over during maneuvering.
4) The movement of the robot is controlled by an RF remote control unit.
5) It is also integrated with a fault detection location unit.
6) It is also integrated with a fault detection and location unit.
7) Simple interface

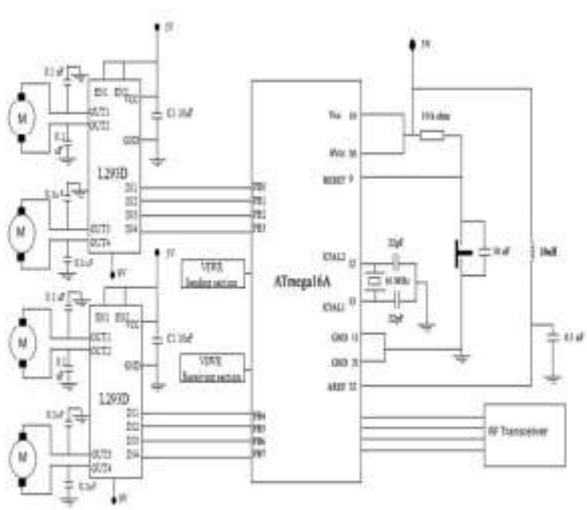


*Fig.2 Cicuitary of Pole Climbing Robot*

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**Robot**

The block diagram of the robot along with the fault location system is shown below. Here we are using ATMEGA 16A microcontroller. Robot uses four metal gear motors for the motion along the pole. The robot is also clamped to the pole to make sure that it it won't flip over or slip during the motion. The four metal gear motors are driven using two motor drivers, each for two motors. The commands to move up and down send from the remote controller is received by the robot and is decoded using an RF transceiver.

The tactile switch connected to the robot is used to stop the upward motion when the robot reaches the top of the pole. The tactile switch is placed on the robot so that, when it reaches the top it comes in contact with the cross arm (or any permanent fitting of the pole) and it gets pressed. The microcontroller is programmed such that when the tactile switch is pressed it stops the further upward motion of the robot along the pole.

The cross arm of the robot having the VSWR module now comes in contact with the transmission lines. Once the arms are in contact it measures the voltage using a voltage divider circuit and provides the input to the microcontroller.

The current is measured using a ratio metric hall sensor which detects the magnetic field around the line and provides a corresponding voltage output which will be proportional to the current in the line.

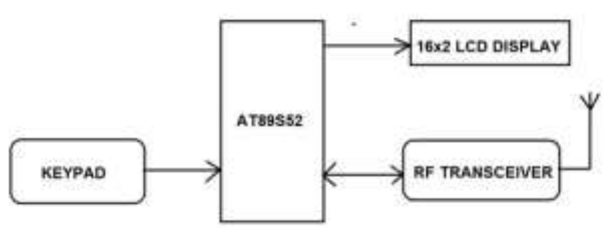
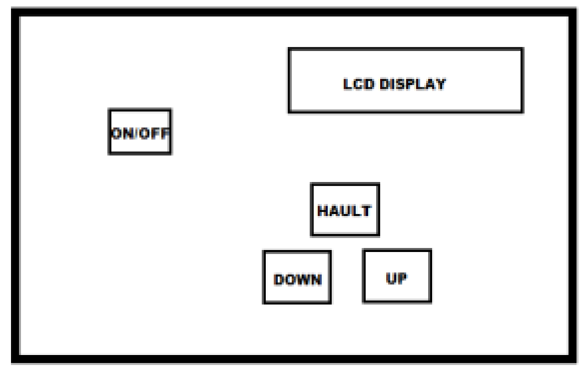



*Fig.3 Block diagram of remote control*

**Remote**

The robot has to be controlled using a remote device. Here we use a RF based remote controller. The voltage measured at the arms as well as the current measured using the hall sensor is relayed onto the remote device. The remote is designed for three basic movement buttons: Start, stop and reverse. A tactile switch is provided on the arm to detect whether the robot has climbed the entire length of the post or pole.

Along with the three buttons on the remote control device a display device is also added on the remote. It displays the voltage current and also whether fault has occurred or not and also where the fault has occurred. The remote control uses a separate microcontroller that takes data from the transmission device on the robot using a RF transceiver.




*Fig,4 User Interface (UI) of remote*

The control algorithm of the robot is given in the flowchart in fig.5. This gives a detailed explanation of the reception of movement commands from the remote control namely upward, downward and stop. The main movement commands are given through a keypad in the remote control and is transmitted using the RF transceiver. The movement commands are received by the robot microcontroller and processed. Before the upward movement, the robot checks whether the arms are touching the transmission line or not. This is done using a tactile switch at the arm of the robot, which if touched or pressed the robot will not move upward. On the stop command, robot will stop its movement. Precaution is to be made to give sufficient power so that the robot will not crawl down. The reverse command will bring down the robot after obtaining the fault analysis data.

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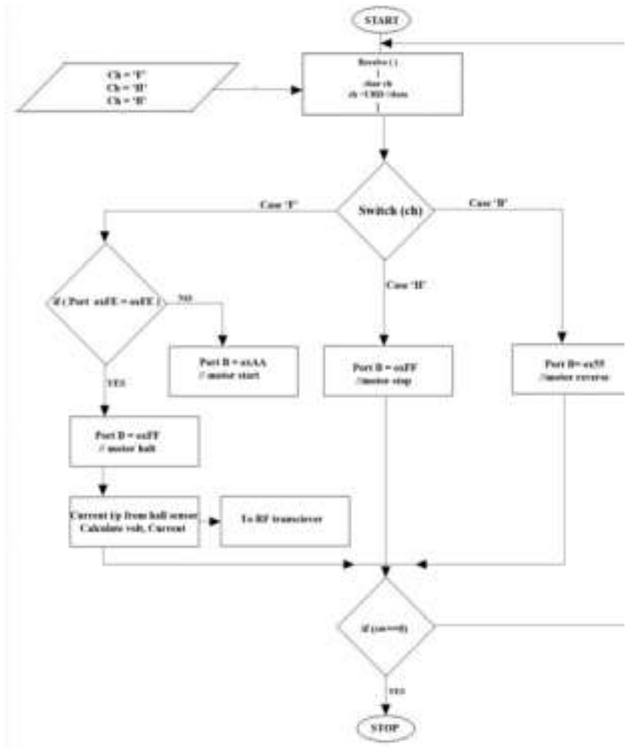


*Fig.4. Motion Control Algorithm of Robot*

## CONCLUSION

As the dependency on electric power supply increases, the chance for failures in transmission line increases. However the usual practice of manual inspection of faults on line is replaced by the proposed robotic fault detection and location. The whole system is broadly classified into two sections as the robot and RF remote. The motion f the robot is controlled by the remote section providing the basic commands of upward,downward movements and stop. This paper proposes the VSWR method of fault location. The fault location detected by the robot is send to the Rf remote section and is displayed in the LCD provided in the robot.

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