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Passive Method to Detect and Locate the Fault in High Tension Power Lines – Line Break

INIGO MATHEW A, RAJKUMAR M
UG students, Department of Electronics and Communication Engineering
SVS College of Engineering, Coimbatore, India Email: inigomathew1@gmail.com

BOSELIN PRABHU S R, RAJKUMAR R
Assistant Professor, Department of Electronics and Communication Engineering
SVS College of Engineering, Coimbatore, India

***Abstract*—** The quality of service provided by any power distribution company purely depends on how fast they respond to faults or failure in the transmission and distribution system. The key challenge here is identifying the exact fault location. Various techniques like wire guide robot and wavelet transform technique can provide the location with approximation from 2 to 5 km. In order to improve the response time the location has to be exact. It can be achieved only if we have dedicated detection elements on that location. But the main constrain in this method the power required to operate the detectors. In this paper we have proposed a method to power up the detector passively so that the location of fault can be identified exactly with 10 m approximation. The fault considered for analysis here is line break.

1. INTRODUCTION

We are surrounded by digital gadgets which are powered by electricity, and it's supported by the transmission line system. Any minute fault or failure in this system will take us back to black-out or even to the Stone Age if the same prevails. In our present system, locating the fault with respect to geographical position is a big challenge. Placing individual sensors over some locations supported by WSN can be adoptable. But the power to operate those WSN is a critical issue. Though battery operated device can be placed, the life of the battery has to be considered, since it's a risky job to replace battery cell on a live wire. Solar operated cells can be deployed, but the cost of the total system will hike. Better option will be a system which will produce current by itself

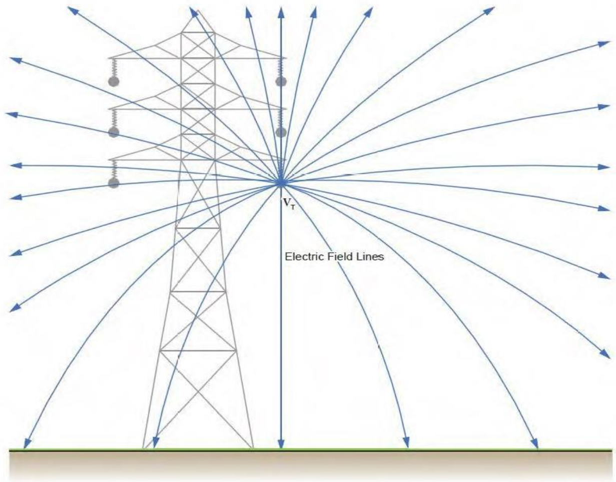

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Fig 1: Magnetic flux/field around a high tension current caring conductor.

When a current is flowing in the wire, it produces some leakage flux around the current carrying conductor, which is shown in the figure 1. This leakage flux increases with the voltage, frequency and area of the conductor. Increasing the frequency will leads to skin effect which further leads to poor efficiency of the transmission system. If we tend to increase voltage we need special step up transformer at the generator side and protection and step down transformers and circuits at the distribution side. Increasing the area of the conductor will leads to added load on the supporting towers [8].We can effectively make use of this leakage flux by using some coils. The basic principle behind this idea is when a current carrying conductor is placed parallel to a conductor adjacent to it, it will induce some voltage/ current on the adjacent conductor [2]. This is because of the leakage flux from the current carrying conductor and this current/ voltage is called as induced current/voltage. But for the flux to link with the secondary conductor the distance has to be certain.

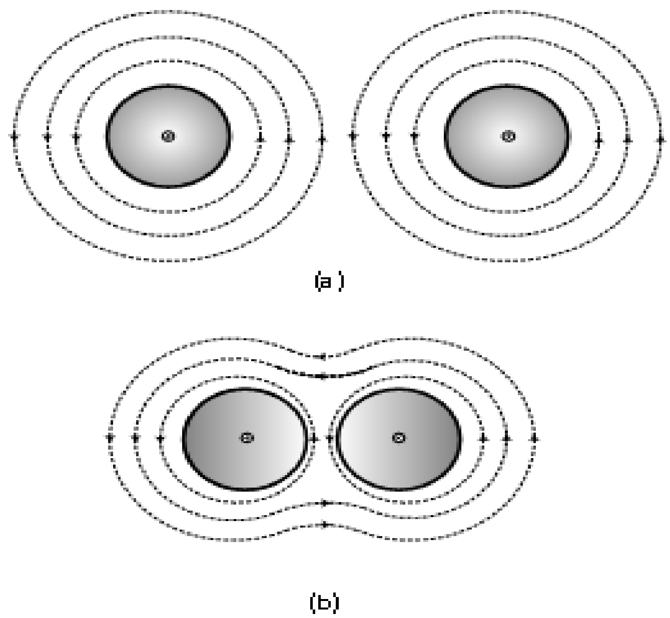

Fig 2: Magnetic field around a single current carrying conductor

In the fig 2(a), the distance between two conductors is not up-to its reach, means the field produced by one conductor is not within the range of another conductor. But in case of fig 2(b) two conductors are placed on a close range so that the field produced in one conductor can be effectively coupled/ linked to another conductor [3,4]. The main aim of the paper is to propose a concept which helps to identify the location of fault using the leaky energy from the system. The way through which field induction or coupling is explained by various scientific concepts.

2. SCIENTIFIC CONCEPTS BEHIND

2. 1. Capacitive Coupling:

When two parallel metallic conductors are separated by an insulator/dielectric material, it leads to storage of charge. The time up to which the charge can be stored is determined by the effective resistance in the circuit. On a capacitor usually one end of the lead is connected with power supply and the other one to the ground creating potential difference. In high voltage transmission line when a conductor with no supply say passive is placed parallel to the active/ live/ hot wire, because of capacitive coupling voltage gets coupled on the passive conductor [9]. This is due to the presence of air which is a dielectric, thus satisfying capacitive condition.

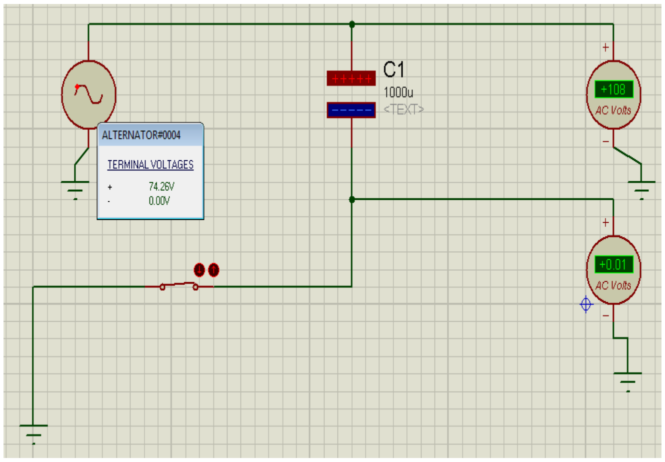

Fig 3: Simulation picture showing capacitive coupling between high tension lines.

Figure 3 is a simulation showing the presence of a capacitive coupling between two conductors. In the above figure alternator is used to provide supply to the active circuit. Passive circuit is connected to ground to show zero potential. Switch is used for the sake of simulation. Assuming the capacitance is due to air as dielectric and voltage gets induced in the passive circuit. If the capacitance value is measured as 1000 micro farad and the supply voltage at that instant is 74 volt, the induced voltage will be 0.01 volt.

2.2. Inductive Coupling

Inductive coupling is due to the presence of electromagnetic force between the conductors. This electromagnetic induction is due to the presence of moving charge carriers in a current carrying conductor. In this case the system acts just like a secondary winding o a transformer with air as core. The electromagnetic field induced on the active line induces some voltage on the passive. One of the methods to evaluate the induced EMF on the passive line is using CARSON equation. For a single phase circuit the equation is given as

$$E_p = -I(Z_p) \qquad (1)$$

Where I is the current on the active line, Zp represents CARSON mutual impedance.

The rate of induced voltage due to induction coupling mainly depends on the total magnetic flux available in the line and the rate of flux linkage. Total magnetic flux is given by the equation as

$$B = \phi/A \qquad (2)$$

Where A refers the surface area available for contact shown in figure 4.

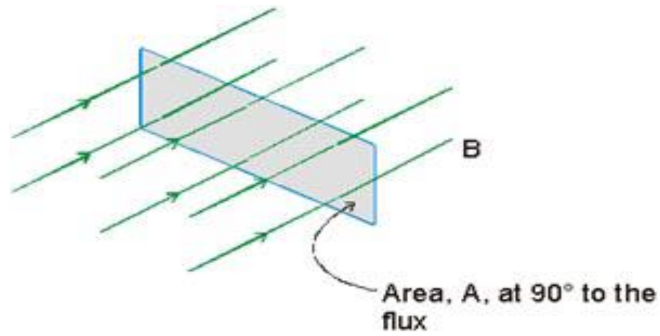

Fig 4: Flux induced in a conductor of area A

Flux linkage depends on the total number of turns in the coil and the magnetic flux present in each coil. Its explained by

$$\lambda = N\phi \qquad (3)$$

when we simulate a high tension line, the active side is considered as ideal and all the losses due to resistive, inductive and capacitive components are neglected. The induced voltage on the passive line is measured using a voltmeter. The passive line has its own power limiting components [5]. The two conductors are assumed to be the primary and secondary of an air filled core transformer, for the sake of simulation. The simulation plot is shown in figure 5.

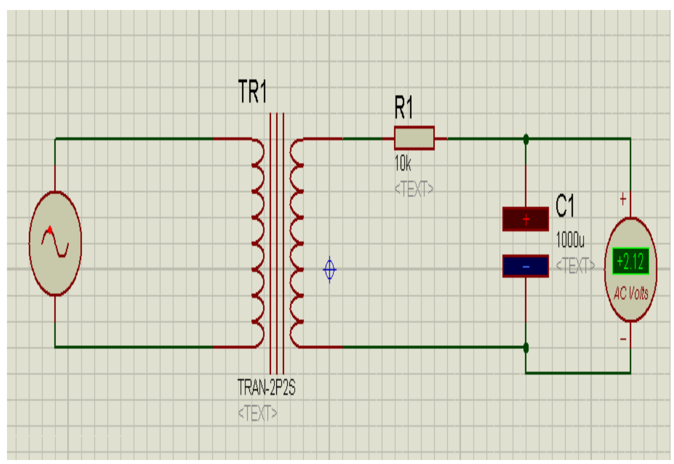

Fig 5: Simulation picture showing inductive coupling using air core transformer.

The voltage and the magnetic flux in the circuit will be phase shifted by 900 [7]. This is made clear in the figure 6, below.

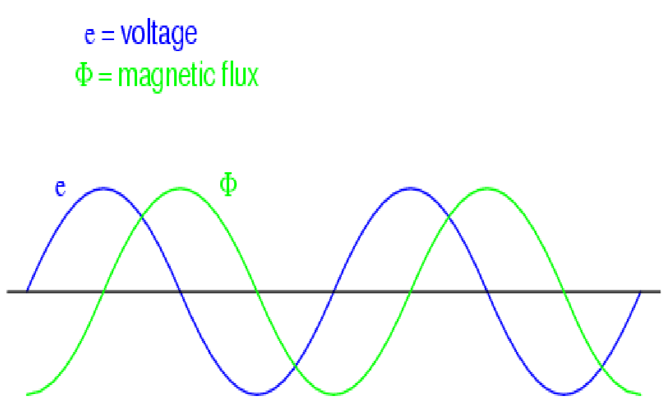

Fig 6: Phase response of voltage and produced flux

From above mentioned concepts we can conclude that some amount of energy can be collected from the leaky Electromagnetic field. This field can be used to detect the presence of power in the transmission system.

3. EXISTING SCENARIO

Current system uses wire glide robots to inspect the high tension power lines. Robot of such kind is shown in the figure 7. The problem with such system is not automatic and its operations are limited.

Fig 7: Wire inspecting robot

Another method available to inspect the high tension transmission lines is by using wavelet transform. In wavelet transform the reflected wave with respect to incident wave is compared to produce an approximation of the fault [1]. But the location of fault can be identified with an accuracy of over 5 KM. The exact location of the fault can only be identified if dedicated elements are placed.

4. PROPOSED CONCEPT

Normally in a high tension transmission line an imaginary field is create far away from the original conductor. This field can induce some current on a nearby adjacent conductor if the conductor is situated well inside the field of the primary [10]. This is shown clearly in figure 8. By increasing the surface area of the secondary/passive conductor the induced field can be improved and the power available in the secondary can be used to power up an electronic circuitry. The imaginary field is shown in the below figure.

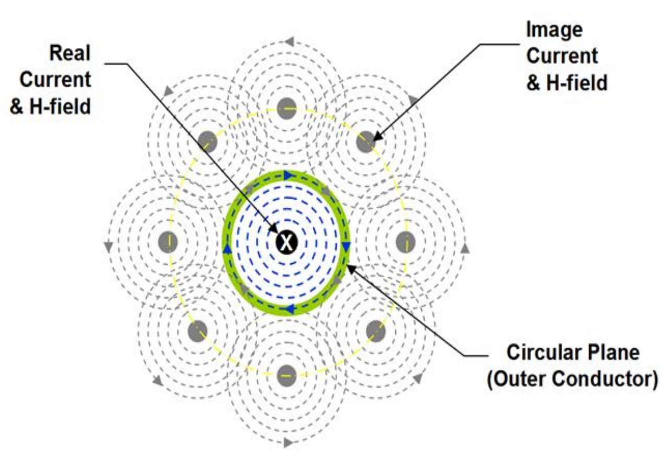

Fig 8: Concept art of image current

Consider a current transformer, which is a special type of instrumentation amplifier which produces some current its passive circuit. This produced current is due to the effect of induction of electromagnetic field and this measure of field gives the available power in the active line [6]. But the problem with this type of circuit is they are manual hand healed devices.

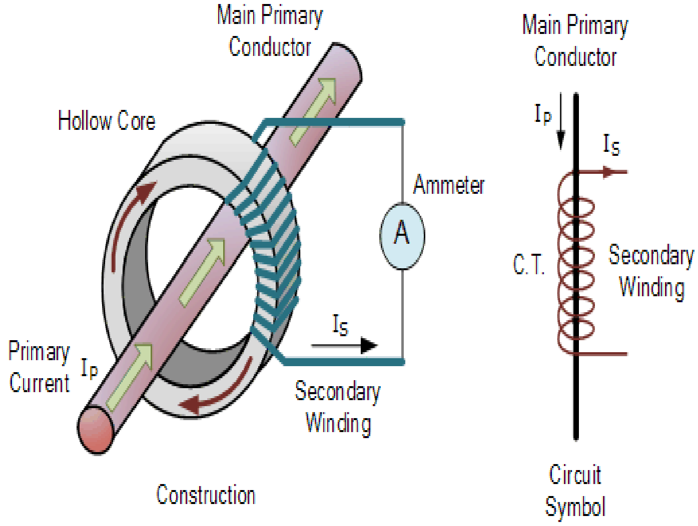

Fig 9: Principle of current transformer.

Above figure 9 shows the working principle of current transformer. The basic block given below shows the working principle of proposed concept. In the figure 10 consider the primary side of the transformer as the active line and the secondary side as passive line [11]. The current/voltage induced in the passive line is given to the power supply cum decision maker circuit.

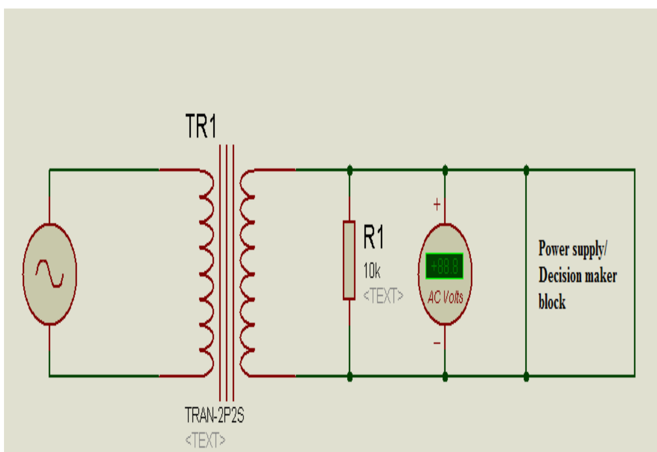

Fig 10: Simulation picture of proposed concept.

4. 1. Power Supply Circuit

The power required for the circuit operation is obtained from the induced current in the passive circuit. The power available in the passive circuit is improved by multistage instrumentation amplifiers, connected in a cascaded fashion, provides a stable output to the decision maker.

4. 2. Decision Maker

This circuit provides the output as 1 if the circuit is switched ON and 0 if the circuit is switched OFF. This logic is connected directly to the presence of power in the transmission line. If the high tension transmission line (Active line) is intact, there will be power induced in the passive line. This passive line will helps to power up the circuit and makes the output of the decision maker output as logic 1

If there is no power on the active line obviously there will not be any power induced in the passive line resulting the output of the decision maker as logic 0.

Using the state of logical output the state of the transmission line can be determined. This logical output can be transmitted to a remote station from where a large power grid can be monitored effectively.

5. CONCLUSION

Methods like wavelet transform cannot provide the exact location of the fault, but it can provide information regarding the type of fault based on the pre-sampled values. In wire guided robotic inspection method, the robot has to be placed manually in the live/ hot wire and it need to be controlled manually, decreasing the system efficiency. Another problem is the endurance, since it's a batter operated device, and high capacity batteries are limited by the load bearing capacity of the transmission cable.
In our method a circuit with reduced size and weight is placed in the transmission line. Since this circuit doesn't need any batteries to provide supply, the endurance of the system can be improved. If the position of the circuit is known, the position of the fault can also be identified.

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