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Accurate Fault Location Estimation in Transmission Lines

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Abstract: **In trendy power transmission systems, the double-circuit line structure is increasingly adopted. However, owing to the mutual coupling between the parallel lines it is quite difficult to style correct fault location algorithms. Moreover, the widely used series compensator and its protecting device introduce harmonics and non-linearity's to the transmission lines, that create fault location a lot of difficult. To tackle these issues, this thesis is committed to developing advanced fault location strategies for double-circuit and series-compensated transmission lines. Algorithms utilizing thin measurements for pinpointing the situation of short-circuit faults on double-circuit lines square measure planned. By moldering the initial net-work into 3 sequence networks, the bus ohmic resistance matrix for every network with the addition of the citations fault bus may be developed. It's a perform of the unknown fault location. With the increased bus ohmic resistance matrices the sequence voltage amendment throughout the fault at any bus may be expressed in terms of the corresponding sequence fault current and also the transfer ohmic resistance between the fault bus and the measured bus. Resorting to tape machine the superimposed sequence current at any branch may be expressed with relevancy the pertaining sequence fault current and transfer ohmic resistance terms. Obeying boundary conditions of different fault sorts, four different categories of fault location algorithms utilizing either voltage phasors, or phase voltage magnitudes, or current phasors or section current magnitudes square measure derived. The distinguishing characteristic of the planned methodology is that the information measurements need not stem from the faulted section itself. Quite satisfactory results are obtained victimisation EMTP simulation studies. A fault location rule for series-compensated transmission lines that employs two-terminal asynchronous voltage and current measurements has been implemented. For the distinct cases that the fault happens either on the left or on the right aspect of the series compensator, 2 subroutines square measure developed. In addition, the procedure to spot the proper fault location estimate is represented during this work. Simulation studies disbursed with Matlab Sim Power Systems show that the fault location results square measure terribly correct.**

Keywords: **Ohmic Resistance, Transmission Lines, PMU, DFR, VCR, EMTP, MOV.**

1. INTRODUCTION

Power transmission lines play a very important role in delivering power safely and continuously. Trendy power systems cowl an oversized and are exposed to external events and circumstances like lightening, falling trees, dirt, animals, ice, etc. These events typically would cause faults rendering the lines out of service. Upon incidence of the fault it's of significant importance for the utility company to send out the upkeep crew to repair the faulted part and to revive the service as shortly as doable. The company's ability to try and do therefore depends on quick and correct fault location. There square measure eleven varieties of short-circuit faults which will occur on transmission lines: single line-to-ground faults (a-g, b-g, c-g), line-to-line faults (a-b, b-c, c-a), line-to-line-to-ground faults (a-b-g, b-c-g, c-a-g), and three-phase faults (a-b-c, a-b-c-g). Single line-to-ground faults square measure the foremost common form of fault sometimes caused by lightning stroke.

Three-phase faults square measure the smallest amount common form of fault. Most transmission lines posses a single-circuit line structure. On the opposite hand, in trendy power systems double-circuit transmission lines are more and more adopted, primarily as a result of they will improve the reliableness and capability of energy transmission. Owing to the mutual coupling between the parallel lines it's still difficult to design Associate in Nursing correct fault location rule the broader application of double-circuit lines. The Series Compensator (SC) may be a device that's typically put in for long transmission lines to boost power transfer capability, enhance facility stability, damp facility oscillations, etc. The SC device may be either a electrical condenser bank or a thyristor-based power controller, that is sometimes protected by a Metal compound Varistor (MOV). For such series-compensated lines the harmonics and non-linearity's introduced by the SC and its MOV create line protection and fault location a lot of difficult for analysis reports are undertaken on quick and correct fault location algorithms for single-circuit, double-circuit and series-compensated transmission lines. They can be classified into the subsequent four categories: phasor primarily based, time-domain based, traveling-wave primarily based, and others. Phasor primarily based algorithms take terminal voltage and/or current phasors as input. The method includes one-terminal, two-terminal and multi-terminal. In high-speed tripping applications it's fascinating for the fault location to be completed before the present disappears owing to relay operations. For phasor based algorithms the acquisition of high-accuracy phasor estimates has to get at least one cycle of information. So the algorithms during this class aren't linear unit for high-speed applications.

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Instead, some time-domain algorithms are developed for single-circuit networks as an example, solely needs an information window of 1/4 of a cycle, satisfying the need of high-speed fault location. Represented by references the traveling-wave primarily based algorithms use the return time of the reacted waves traveling from the fault purpose to the road terminal as a live of distance to the fault. Different algorithms victimisation ripples techniques, article neural networks.

In general this square measure the key sources of error in any fault location algorithm:

1) Line imbalance. Algorithms developed below the idea of the backward lines square measure applied to un transposed lines, and can introduce errors in consequence.
2) Shunt capacitance. Most algorithms utilize the lumped parameter model that neglects the charging effect of the lines. However, for long transmission lines Associate in Nursing exact illustration of the road has to totally contemplate shunt capacitance.
3) Fault resistance.
4) Load current.
5) Supply impedances. In sensible power systems the equivalent supply ohmic resistance of every terminal changes unendingly.

1.1. Objectives

In recent years intelligent instruments like Digital Fault Recorder (DFR) and Phasor measuring Unit (PMU) are put in power systems. These devices are ready to give extremely correct phasor measurements. The foremost distinguished benefit brought by the PMU is that the synchronization of phasors, that greatly simplifies the fault location downside and improves the fault location accuracy. However, due to the valuable value of those units they're solely sparsely deployed within the networks. Having the castrate conditions in mind this thesis focuses on a network analysis approach that's supported the bus ohmic resistance matrix technique. The approach results in two sorts of correct phasor-based fault location algorithms for double-circuit lines. They utilize thin voltage phasors or current phasors, severally. A large variety of observance devices like power quality meters are deployed within the systems. Some meters will solely capture the voltage magnitude (also called voltage sag) or the present magnitude rather than phasors. The voltage and current waveforms at one terminal of a double-circuit line that has been effected by an a-g fault or Associate in Nursing a-b-c fault square measure shown in Figs. 1.1 and 1.2, severally. The question a way to exploit magnitude information in locating faults is of sensible significance. Algorithms that use voltage or current magnitudes for fault location on double-circuit lines are extensively explored during this thesis. In Associate in Nursing report to exactly find the fault on series-compensated single-circuit trans-
mission lines, a completely unique methodology using two-terminal asynchronous voltage and current phasors has been devised. In distinction to established strategies

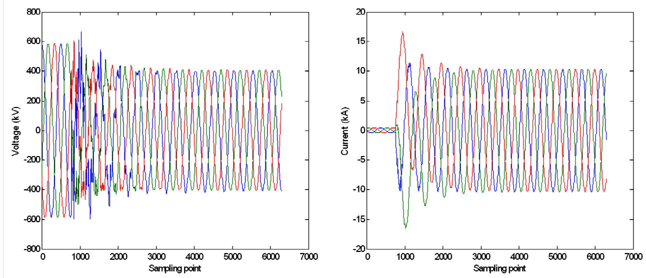

Figure 1.2: Voltage and current waveforms throughout a-b-c fault. avoids the utilization of the equivalent voltage-current (V-I) model of SCs & MOVs.

1.2. Proposed New Methods

The fundamental principle of the planned fault location methodology for double-circuit lines is to feature to the initial network a bus wherever the fault happens. Hence, the bus ohmic resistance matrix is increased by one order. Then, the driving purpose Impedance of the fault bus and also the transfer ohmic resistances between this bus and different buses square measure expressed as functions of the unknown fault distance. supported the definition of the bus ohmic resistance matrix, the amendment of the sequence voltage at any bus during the fault is developed in terms of the corresponding transfer ohmic resistance and sequence fault current. looking on the boundary conditions for different fault types, we will get the fault location equation victimisation voltage phasors as input. Two chapters of this thesis square measure dedicated to fault location algorithms that use voltage phasors. Those supported the lumped parameter line model square measure investigated in Chapter two, whereas those adopting the distributed parameter line model instead, are addressed in Chapter four. When the relationships between section and sequence voltages/currents square measure established through symmetrical part theory, we will use section voltage magnitudes to solve the fault location downside. This can be mentioned in Chapter two. Based on constant increased bus ohmic resistance matrix, Voltage and Current Relation (VCR) square measure utilized. Currently the amendment of the present at any branch may be expressed as a perform of the relevant fault current and also the transfer ohmic resistance terms associated with the 2 ends of the branch. With this result, fault location algorithms
based on either current phasors or section current magnitudes square measure developed during this dissertation. An entire description of this subject is given in Chapter three. I have utilized the distributed parameter line model for fault location in series.

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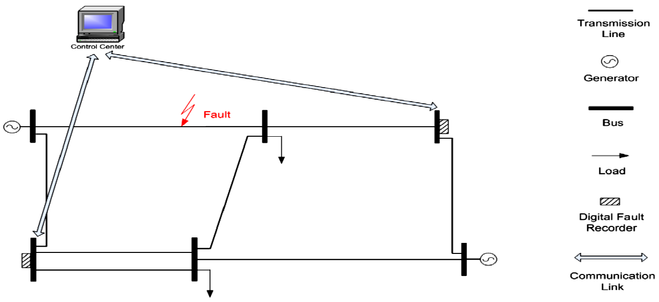

Figure 1.3: A sample wide space observance system.

2. FAULT LOCATION USING SPARSE VOLTAGE MEASUREMENTS BASED ON LUMPED PARAMETER LINE MODEL

Diverse fault location algorithms on double-circuit lines are developed within the past many decades. In general, existing algorithms need voltages and/or currents from one or 2 terminals of the faulted section or all the terminals of the network. For the state of affairs wherever solely thin measurements, which can be far-flung from the faulted section, square measure accessible, these strategies aren't appropriate any longer. Reference gap by proposing a completely unique fault location methodology for single-circuit lines supported the bus ohmic resistance matrix technique. The distinctive characteristic of this methodology is that it solely demands voltage measurements from one or 2 buses, which may be distant from the faulted line. As a supplement to the add, the scenarios wherever solely voltage magnitudes square measure accessible square measure addressed. Drawing on the bus ohmic resistance matrix technique adopted in, this chapter any develops novel fault location algorithms for double-circuit lines supported the lumped parameter line model. Looking on the input of the tactic, fault location techniques utilizing voltage phasor measurements and section voltage magnitudes square measure enforced, severally. The measurements can be from one or a lot of buses and don't have to be compelled to be taken from the faulted line. The work is predicated on the idea that the network information are best-known and also the network is backward. Additionally, it's assumed that the faulted 10 section may be determined before hand supported relay operations. Fault kind classification result, if necessary, is offered. The planned methodology is applicable for basic frequency phasors, to that all the voltage and current quantities refer throughout the thesis.

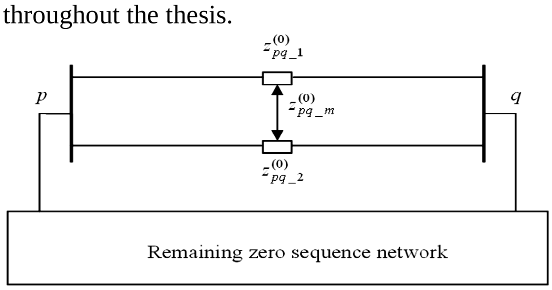

Figure 2.1: Pre-fault zero-sequence network.

3. FAULT LOCATION USING SPARSE CURRENT MEASUREMENTS BASED ON LUMPED PARAMETER LINE MODEL

In Chapter two, fault location methodology victimisation thin voltage measurements has been introduced. By taking advantage of constant bus ohmic resistance matrix technique, fault location algorithms for double-circuit lines victimisation thin current phasors and current magnitudes are developed during this chapter. This work is extended from the fault location algorithms victimisation thin current measurements for single-circuit transmission lines. Current measurements from one or a lot of branches square measure taken as input, which can be far-flung from the faulted section. The faulted double-circuit line is sculpturesque by the lumped parameter line model that ignores the shunt capacitance of the long lines. the subsequent assumptions square measure utilized: (1) the network information square measure available; (2) the network is transposed; (3) the faulted section has been determined in advance; (4) Fault kind classification result's best-known.

3.1. Simulation Studies

In order to guage the developed fault location algorithms, simulation studies have been conducted and results are shown during this section. The methodology is to simulate faults of different sorts, locations and fault resistances for the studied system with EMTP. The present phasors extracted from the generated current waveforms victimisation distinct Fourier remodel square measure fed into the developed algorithms to calculate the fault location. The waveforms of regarding eighth cycle once fault beginnings are captured to get the phasors. The sample 4-bus facility utilized in Section two.4 is shown here once more in Fig. The doable current measurements and their own directions for every branch are specified in Fig. The system is modeled in EMTP supported the lumped parameter line model while not considering load and shunt capacitance of the road. The location of the fault is defined because the distance between the fault purpose and bus. The fault location accuracy is evaluated by proportion error defined in equation.

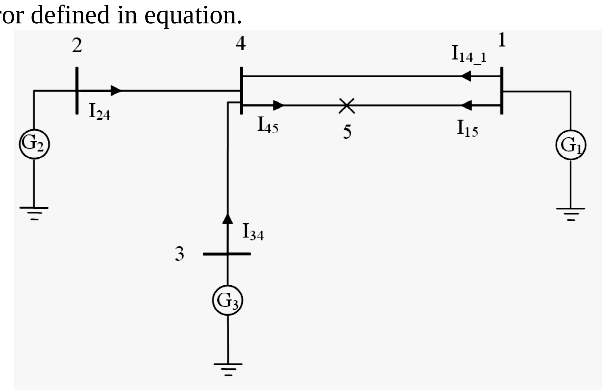

Figure 3.6: The diagram of studied 4-bus facility with current indicated. Next, fault location results utilizing current phasors and section current magnitudes are reported, severally.

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4. FAULT LOCATION UTILIZING SPARSE VOLTAGE MEASUREMENTS BASED ON DISTRIBUTED PARAMETER LINE MODEL

The fault location methodology planned in Chapter two is predicated on the lumped parameter line model while not considering the shunt capacitance. For long transmission lines, it may cause significant errors. This chapter has developed correct fault location algorithms supported the distributed parameter line model, which totally takes the charging effect of the lines into thought. Thin voltage measurements square measure utilized and no current measurements square measure needed. The network information square measure assumed to be best-known and the network is backward. The faulted section has been pinpointed ahead from relay operations. Also, the fault kind classification, if needed, has been carried out before applying fault location algorithms.

The positive-sequence equivalent nine models for the double-circuit line is not any different from the single-circuit line since there's no mutual coupling between the parallel lines that is well represented in classical textbooks. However, the zero-sequence double-circuit line model supported the distributed parameter line model has not been discussed in any textbooks owing to its complexness. In reference, by decoupling the zero-sequence parallel lines into 2 freelance modes, the equivalent nine models for double-circuit lines having either identical or different line parameters is established. In this thesis, a different approach strictly in time-domain is provided. The constructed equivalent nine model is that the same as that of. The planned time-domain approach is simply applicable to the state of affairs wherever the road parameters of the parallel lines square measure identical. In this section, all the quantities talk over with zero-sequence elements unless other-wise specified. A schematic diagram of a zero-sequence double-circuit line is delineated in Fig. 4.1. The causing and receiving ends of the road square measure denoted as S and R.

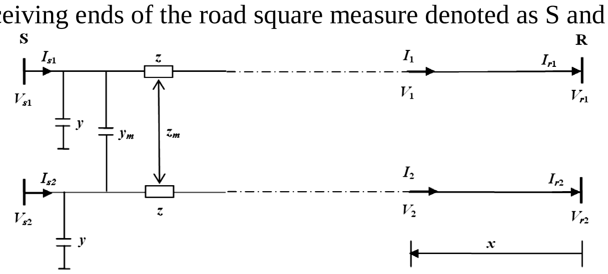

Figure 4.1: reciprocally coupled zero-sequence networks of a parallel line.

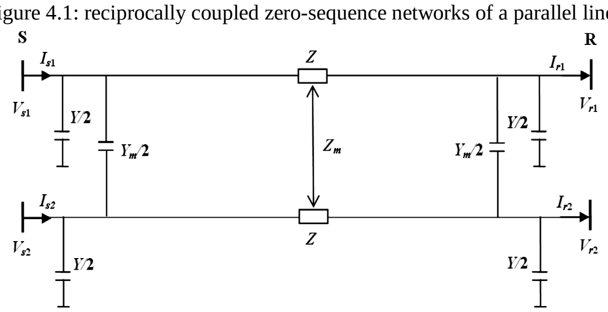

Figure 4.2: Equivalent nine model of the zero-sequence double-circuit line.

5. FAULT LOCATION FOR SERIES-COMPENSATED LINES

Several intelligent fault location algorithms having the ability to avoid the equivalent V-I model of SC& MOV bank are developed within the past few years. Reference proposes a synchronous 2-end rule that features two steps: the at one time step ignores the existence of SC& MOV bank and calculates a pre-location of the fault; the second step iteratively computes the voltage on the correct aspect of the compensation device and corrects the situation of the fault. Reference derives Associate in nursing analytical formula of the overall fault loop, from that each fault location and fault resistance will be solved victimisation repetitious methodology. The synchronization angle is computed ahead using pre-fault measurements or typically fault quantities. Each square measure independent of the model of series compensator and utilize distributed parameter line model, whereas considers the double-circuit salaried line and a lot of general unsynchronized case. Aiming at the series-compensated single-circuit line, a completely unique fault location methodology based on the distributed parameter line model is conferred during this chapter. It utilizes unsynchronized two-terminal voltage and current phasors as inputs. As in , the currents owing out of the fault purpose square measure developed in terms of unknown fault location. Then boundary conditions of different fault sort's square measure exploited to derive the fault location formula. The synchronization angle may be calculated victimization pre-fault quantities or fault quantities. The fault ohmic resistance is assumed to be pure resistive, the fault kind is assumed to be best-known ahead from relay operations and the system is backward.

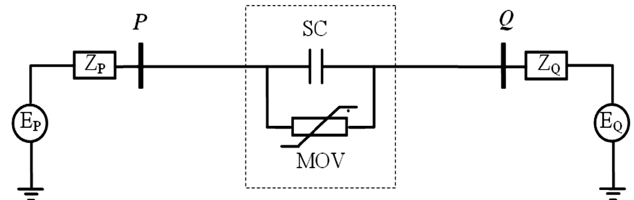

Figure 5.1: A schematic diagram of a series-compensated line.

5.1. Proposed Fault Location Algorithms

A schematic diagram of a series-compensated line is shown in Fig. 5.1. The series electrical condenser is put in place on the line. The

MOV, equipped in parallel with SC, can conduct once Associate in nursing overvoltage across the series electrical condenser is detected. The voltage and current phasors from each ends square measure available. The series compensation device divides the line into 2 sections. Since on that aspect the fault happens is unknown to United States of America, it's necessary to develop 2 subroutines addressing doable fault on either aspect. The software system one and 2, that assume the fault on the left and right aspect of the series compensation

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device square measure derived very well. Later, the principle to come to decision verity fault location estimation is illustrated.

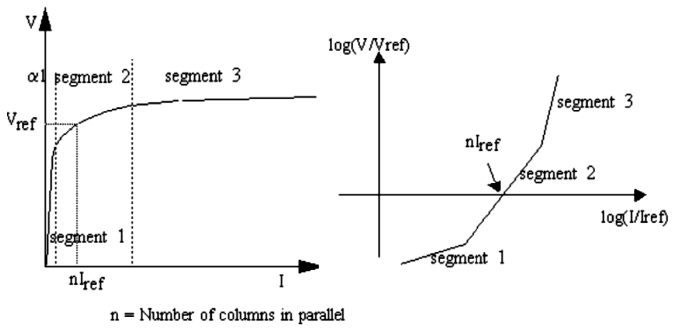

Figure 5.2: V-I characteristic of MOV.

6. CONCLUSION

Short-circuit faults square measure the foremost common and severe threat to power transmission lines. With today's power networks typically stretching many miles over advanced geographic tract, precise location of the fault in a very timely fashion will speed up restoration and scale back loss of revenues for the utilities. For many decades transmission line fault location has been a very important subject of analysis and lots of algorithms have been developed. In this thesis advanced fault location strategies for double-circuit lines and series-compensated single-circuit lines are planned, taking advantage of intelligent devices like DFR, PMU and power quality meter. For double-circuit transmission lines I actually have developed different fault location algorithms supported the lumped parameter line model. They utilize either thin voltage phasors, or phase voltage magnitudes, or current phasors, or section current magnitudes. Accurate fault location algorithms that use voltage phasors have additionally been implemented, taking into consideration the charging effect of transmission lines within the distributed parameter line model. Simulation studies with EMTP have shown that the proposed algorithms square measure ready to yield quite precise fault location estimates.

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