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A novel protection scheme for transmission lines utilizing positive sequence fault components: A review

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Abstract The transmission system line is one of the most important aspects of the overall network. Transmission lines transport a huge amount of energy. The demand for energy as well as its delivery has grown substantially in recent years, and a distribution system's primary function is to carry electrical current from an initial location to utility grid. The greater emphasis on preventing electricity attenuation has resulted from the explosion between limiting output and a huge claim. In long distance networks, line inefficiencies, as well as speculative aspects such as physical losses and various technical losses, are substantial. Generally, investigation of failure of system is a highly focused topic in power systems development to remove fault in such a brief time and re-establish power station as fast as feasible with the least amount of disruption. However, detecting a failure that affects the transmission line is a difficult process since it requires both investigating the fault and enhancing the system's dependability. Considering all of the characteristics that interconnect the entire power system, the transmission line is vulnerable. The goal of this research is to examine transmission line breakdown protection.

Keywords Fault Detection, Fault location estimation, Positive Sequence Admittance, Transmission Line .

1 Introduction

Transmission lines, which transport electrical power from generating stations to load centers, are the most important portion of the distribution system. Power system engineers have been a target for detecting and discovering defects as of the distribution and transmission system's development As long as the issue is detected, it provides useful aid in maintenance of the unit, as well as a simple method of isolating the element that is causing the problem. With the help of this, it supplies a safe choice for protecting the machine from any hazards.[1]. As a result, it's critical to notice the defect; otherwise, the issue will create any disruption, which will add to the time it takes for you to work with the networked system, which is limited[2]. The dwelling of this system of transmission was built to examine the location of this problem and to provide isolation just where the risk actually arises. In a nutshell, the stimulant method aids in the identification and concentration of the malfunction. Something like a fixed capacitor allows for a consistent voltage to be achieved. Over through the line, the inductance of series capacitors could be lowered by (L di/dt). If the cable current exceeds the voltage, the mean voltage rises. On the other hand, if voltages is dropping back due to current flowing, there may be a loss of power. In this case, the volt that increased and decreased fell due to the capacitor present in series, precisely even if the circuit inductance for such series fully compensated line was lower than for the unpaid line [3].

The revolution adjoining certain information that is electronic communication technology triggered a simple improvement in being familiar with the attributes with regards to power system, slowly but surely progressing through use of different usefull set of tools like S-C-A-D-A, in order to obtain the synchronized phasor measurements also called as SPM. S-C-A-D-A's information and facts cost is somewhere around 1 or 2 seconds, while SPM's price this is certainly reporting 50 phasors per second utilizing a discontious this can be transform (FCDFT) that is certainly full-cycle. This reporting that is high-speed in adequate SA in electrical power system[4].

Overhead transmission outlines go through 2 forms of faults for example. temporary and fault that is permanent. Statistical analyses represent that, more than 80% of errors on overhead outlines are short-term as a whole. Because of the fact short-term defects only exists just for a very very small timeline, consequently they could be eradicated just by picking out the phase that is certainly faulted. Ergo, ensuring power this is actually maximum steadiness and have never allowing the difficulty to reach additional material is essential. With that said, permanent faults can not be cleared until they have been fixed. As a result, often used during persistent defects may increase the likelihood of the unit being damaged. Short-term faults could be resolved by turning on the breaker of the circuit (or termed as a Circuit Beaker) and deionizing the arc course, which is in keeping with the discussion. And so the chance of restoring power ascends[5].

Conventional singular auto-reclosing techniques use a set dead period and are unable to determine the cause of the failure. This implies that re-closing can occur throughout a fault or could re-start the fault, resulting in over-voltages all across breaker[6].

The most specific source of concern is the investigation of defect in the electricity business. However, for fault detection, certain protection devices (relays) are utilised, along with specific control equipment and recording devices, many of which are then used terminate the process at which problem is occurring in the system [6]. The most crucial task is to gather all information about the defect so that it may be investigated and corrected as quickly as feasible. Many scholars have sought to understand the skills for locating problem spots in distribution and transmission networks using A-I approaches like as "fuzzy set theory and artificial neural networks."

2 Problem Definition and Challenges

Now a day's maximum connected loads are non-linear which the major cause of power line harmonics are. The neutral signal generated by these harmonics may be greater than the individual phase current. It can be analyzed that I1 is the fundamental amplitude, and the ins are the odd resonant amplitudes; and for each of the harmonics, shifting of phase are also denoted. Let just take into account a load which only tends to produce 3rd current flow, which is the prominent resonance frequency in most triple-phase system. Since there is the presence of third-harmonic currents, there would be the 120-degree shifting of the phase in order to obtain the fundamental outcome in a 360-degree current flowing for the third harmonic. It thus signifies that now the third-harmonic currents from every line conductor are really in phase, while the neutral current constitutes the sum of the magnitude out of each phase.

$$In = 3Ih3$$

It is important to realize that the apex of the 50 Hz fundamentals is 1.0 amps and the max of the 150 Hz third harmonic is 0.3 amps, and it is difficult to anticipate the periodic attenuation since each implementation will get a unique harmonic shape.

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In three phase power systems, there seem to be three forms of harmonics that flow. These include [7]:

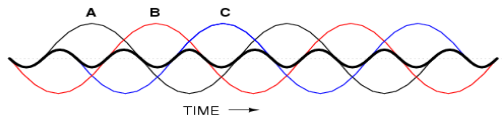
- Positive Sequence
- Negative sequence
- Zero sequence

Three sinusoids are shifted 120° from everyone else in the positive-sequence set, well with standard A-B-C phase rotation for instance., 0°, -120°, 120°. The negative-sequence frequency components are likewise deviated 120°, but rotate in the reverse polarity, for example A shifts to 0 degrees, C to 120 degrees and B to -120 degrees. The zero sequence's signals are in sync with one another as A,B and C all of them with zero degrees. The harmonic phase sequence can be ascertained by incrementing the chromatic number h using the normal positive-sequence-phase cycle in a vast equitable three-phase system For example, if h=2 is the modulating frequency, we obtain 2different type of shifts that is 0, -120°,120° or 0°, 120°, -120°, which seems to be the negative sequence, however for the third harmonic, h = 3, we get 3 = 0°,120°, 120° or 0°, 0°, 0°[8]. Odd-harmonic prime example rotations are as follows: Because a deformed signal Odd-harmonic phase sequence rotations in sources of power with just odd-harmonic components are as follows:

1. Harmonics with order h = 1, 7, 13,... are usually in a positive pattern.

2. Harmonics with h = 5, 11, 17,... have a negative recurrence.

3. The triplen h = 3, 9, 15,... are usually in the zero order



Harmonic currents of Phases A, B, C all coincide, that is, no rotation.

*Phase sequence = **A-B-C***

Fundamental	A 0°	B 120°	C 240°
3rd harmonic	A' 3 x 0° (0°)	B' 3 x 120° (360° = 0°)	C' 3 x 240° (720° = 0°)

Fundamental	A 0°	B 120°	C 240°	A-B-C
3rd harmonic	A' 3 x 0° (0°)	B' 3 x 120° (360° = 0°)	C' 3 x 240° (720° = 0°)	*no rotation*
5th harmonic	A'' 5 x 0° (0°)	B'' 5 x 120° (600° = 720° - 120°) (-120°)	C'' 5 x 240° (1200° = 1440° - 240°) (-240°)	C-B-A
7th harmonic	A''' 7 x 0° (0°)	B''' 7 x 120° (840° = 720° + 120°) (120°)	C''' 7 x 240° (1680° = 1440° + 240°) (240°)	A-B-C
9th harmonic	A'''' 9 x 0° (0°)	B'''' 9 x 120° (1080° = 0°)	C'''' 9 x 240° (2160° = 0°)	*no rotation*

Fig. 1: Different types of Harmonics

Positive sequence harmonics, such as the 7th, "rotate" in much the same series as that of the essential, while negative sequence harmonics, including the 5th, "rotate" in the exact reverse sequential manner of the fundamental. Zero sequential harmonics, such as that of the 3rd and 9th shown according to the above table, do not even "rotate" either because they're in phase with one another. As a result, even during implementation of the algorithm, the quality of the utility grid must be considered. [9].

2.1 Power Line Harmonics:

A lot of scientists/researchers have conducted studies on this issue, although some of the articles are covered here. Many scholars have sought to understand the capabilities for locating problem spots in distribution and transmission networks using AI - based approaches like as fuzzy set theory and artificial neural networks.

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3 Comparisons of Related Work Methods

The table below compares different failure and protection-based algorithms based on the algorithm's approach. The quantity of data and parameters related to the design of such an algorithm are used to describe complexity. Further, the complication level is influenced by the length of time it takes to build and test features, and also the reliability, convergent, and variation required, as well as the amount of data required. [10].

3.1 Intelligent Fault Analysis Method:

Intelligent fault analysis is a technique for analysing faults in transmission lines employing a phasor measurement unit (PMU) with an auto-reclosure prevention strategy [11]. Virtual systems for getting ideal phenomenological facts with adequate characterisation and quality transmission have been built using LabVIEW and National Instruments (NI) data processing devices.The major goal of the study is to detect and understand transmission line problems using SPM acquired by the use ofmeasuring unit of phase, and thus to safeguard the system through using auto - reclosing signals. Phaselet parameters for observation and understanding are included in the proposed methods. For understanding, a particle swarm optimised extreme Machine Learning i.e. MI approach was applied to improve accuracy. In the event of a transient defect, a protective strategy is used that employs auto-reclosing to reduce power failure and speedy rapprochement of the transmission line. The generated algorithms were verified on a real-world experimental transmission system. Because the tool LabVIEW technology was been used to simulate, it has visual indications that enable the central controller to make effective strategic control decisions.

3.2 Auto reclosing scheme:

Another option for EHV power lines is single phase adaptive auto - reclosing methods. The primary goal of an Adaptive Auto - reclosing (AA) technique is to locate the earliest and safer reenergization point while avoiding additional trips. Figure 2 depicts the fundamental ASPAR procedure. Figure 2 depicts the many steps of an ASPAR system. Figure 2(a) depicts a power system's usual operating or pre-fault status. As indicated in Fig. 1b, a singular line to earth faults (temporary or permanent) is initiated on a phase. The faulty phase is segregated by the usual protection, which is shown in the Figure 2(C). The nature of the fault detection is done, while the event for a transitory issue, other is allowed to entirely extinguish, as shown in Figure 2(D). The last figure indicates that the curve has been controlled, and now it is relatively safer to reconnect the faulty phase [12].

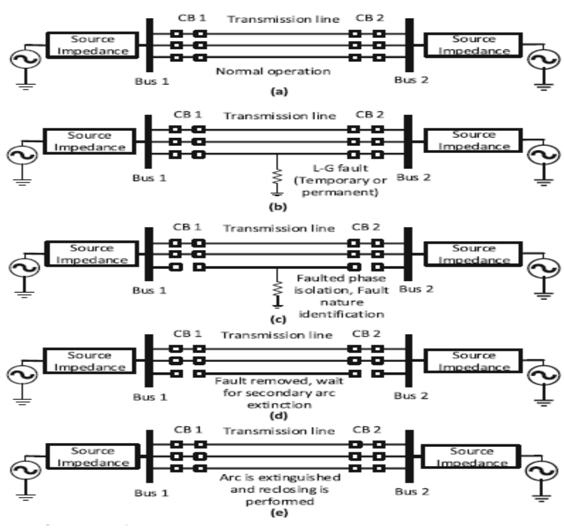

Fig. 2: Fault removing using auto reclosing scheme

Reclosing is halted if a persistent defect is discovered. Conversely, before reclosing, the scheme checks for an arc extinction moment. Residual voltages will exist on the line after the secondary spark has been extinguished, indicating

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the optimal reclosing moment. This single-phase tripping mechanism is only capable of lasting a few seconds. Otherwise, this imbalanced position may be polarizing the proper functioning of the electrical system.

3.3 Utilizing positive sequence fault components scheme:

Other technique is a novel line - to - line protection scheme that uses positive sequence breakdown aspects, which employs an unique integrative approach of protection relaying technique for identifying faults and estimating their position in overhead transmitting lines. First, the detection method was designed with positive sequence admitting. Following that, a defect location technique based on positive sequential voltage plus current phasors was devised. In the MATLAB environment the proposed algorithms were tested on a single-circuit power line with a frequency of 50 Hz and a voltage of 400 kV. To verify the dependability of this technique, a broad variety of diverse and complex instances were simulated. The results validate the algorithm's precision, as it can produce precise findings under agitated conditions. Furthermore, This approach has been proven to work in both series-compensated and double power grids, exhibiting its benefits. A comparison with contemporary protected relaying approaches establishes the potentiality and reliability [13].

3.4 Standard-Deviation Method :

High resistance faults present a significant issue to conventional fault detection and recognition techniques [14]. The standard deviation and accumulation methods are used in this research to find and classify faults. It is typically constructed in two different types of stages. In order to derive the fault characteristic, the analysis of variance of the actual and virtual connections' recorded current signals is then analyzed. Second, to extend the failure part of the increasing resistance collapse, the progressive technique is applied. The suggested technique is the Standard Deviation Index (SDI), which is calculated for both the three phases and the zero sequence. The proposed technique has been tested in a wide range of fault situations, including a wide range of issue locations, malfunction resistances, and failure inception times. Far-end resistivity circuit failures, terminal collapses, flaws with changed load - carrying angle, quick load shifting, varying sampling rate, inappropriate signaling, All of these issues, as well as a malfunction in the context of series compensation, are solved. The results suggest that the recommended strategy was quite effective well enough in regards of defect resistance out to 1.5k Ohms, adding that this may be detected within such a millisecond of a breakdown onset. Furthermore, the processes' computational efficiency works effectively and is excellent for tech to operate.

3.5Backup Protection Algorithm:

In this article [15], to address the problem of traditional backup protection mal-operation in overstressed power station operating scenarios, a novel broad area backup prevention algorithm based on defective element complex power is proposed. Faulted area identification (FAI) conditions, which have been measured values of collapse part voltages, are used to identify probable defective lines initially. And used the breakdown element voltages and currents provided by phasor measurement devices, the supplied complex energy to both ends of the reported issue lines is computed (PMUs). The proportion between overall and differential of administered complex power both towards endpoints of the suspect faulty connections is used as a faulted line identification (FLI) criteria. The proposed computation efficacy is validated by simulation experiments on the IEEE 10 generator

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39-bus network in a variety of scenarios and failure types.

3.6 Wavelet Model:

In [16] a 220 kV power simulation is performed for various fault scenarios on the lines using MATLAB®/Simulink, SimPowerSystem toolbox, wavelet/neural toolbox. Figure depicts a one-line representation of the under considered network. Line voltage signals through both sides of the transmission system are utilised for breakdown diagnosis present at power station. The inputs are samplized at 320 KHz, for a total of sampling rate of 6400 samples each cycle.

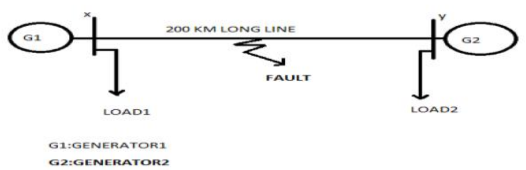

Fig. 3: Wavelet Model

The voltage signals for single cable to earth losses in various fault scenarios were created and considered. As previously stated, the energies of D1 and D5 by each signal's data frame were computed, and the zero sequence current was generally separated and recorded as faulty voltages. The energy value for zero (0) sequential current is however determined for similar frame of data. In MATLAB, a programming code was written to calculate the energy in the very first three data frames separately. By multiplying the graphs result by 6400, you may get the real values. The results demonstrate that the declining of the transitory energy may be used to both locate and categorise the fault. It provides a highly compelling result for fault location and classification.

Grid protection for (HVdc) grids is designed to offer both primary and backup protection. Protective equipment, switches, and breakers are installed at the transmitting system's endpoints. Defect waves are transmitted to the VSC units whenever there is a breakdown in a dc grid. A timing diagram for MT–HVdc grid control is shown in Figure 4. The moment whenever the dc failure occurred is shown by t_0 in this scenario. The problem is detected by the principal protective relays. The PP relay gives a nerve impulse to the associated breaker at time t_1, and the breaker responds by exposing its contacts and cutting the dc defective current at time t_2.

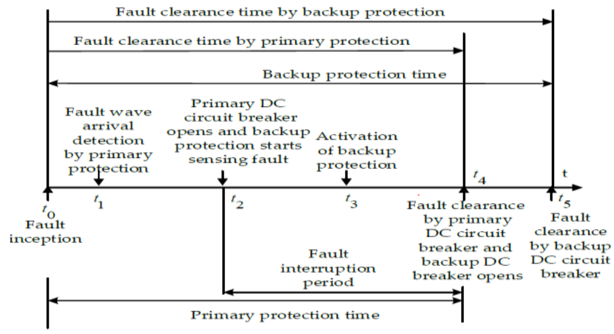

Fig. 4: Full Wavelet Model Explanation

At time t_2, the backup relay detects a fault, and at time t_3, the backup relay generates a trip signal. If main protection fails to prevent the current between times t_2 and t_4, the backup breaker begins its interrupt operation at time t_4. In the time frame between t_2 and t_5, backup protection totally interrupts the fault.

3.7 Artificial Neural Network Method:

A method relying on MATLAB software to identify transmission line faults. The system's information is utilised to educate an artificial neural network that detects transmission line issues. The identification of faults has been accomplished using an artificial neural network [17].

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Another paper demonstrates a correct alternative technique for detecting and classifying problems on transmission lines. The plan is to employ a neural network and a wavelet transform in tandem to select the best solution to the problem. Wavelet transform provides powerful logical, highly rapid, and effective tools for transitory signal in transmission lines that has been utilised in artificial neural network that can distinguish between measured signal and related signal with distinct pattern. It is possible to do this by employing a certain algorithm [18].

3.8 Back-propagation network classifier:

Back-propagation network classifier is the algorithm employed in the study, voltage / current values have been used as inputs for the modeling, and the test technique is a 128 km lengthy dual circuit TL using 35 GVA and five GVA generations, respectively. This model has the following characteristics: 800 Hz sampling frequency, results acquired by 3 sampling data frames, and while amount of neurons of Kohonen is highly depends on the quantity of training dataset. With basic complexity, the misinterpretation rate of this method is less than 1%[19].

The model [20],is evaluated and the values used in this are 50 Hz of frequency, and 390 km Transmission Line, and 500 kV, with both the algorithm that is Bayesian classifier and also the wavelet algorithm'. The characteristics are as follows: 500 kHz sampling rate, Db4 mother wavelet, and 546 fault instances examined for train. The accuracy of the results obtained is 100 percent, but the complexity is high in comparison to the back-propagation network classifier.

Table 1 Comparative Analysis

Technolgy	Advantage	Disadvantage
ANN Technique[22]	The accuracy of ANN in detecting the specific type of fault is rather high, and its execution is uncomplicated.	For high-dimension issues, the training method is fairly complicated.
	It's simple to use, and just a few variables need to be tweaked.	The gradient-based backpropagation neural approach for non-linear segmented pattern recognition provides a local optimal solution.
	It may be used to solve a variety of real-world challenges.	In the BP method, ANN provides gradual convergence.
	There is no need to reprogramme ANN since it learns.	The choice of the initial amount of weight limits network - connected determines convergence.
Fuzzy Methods[23]	To handle ambiguity concerns, a basic 'if-then' relationship is utilised.	There is no evidence of robustness.
		For big training data, specialists are required to define the membership function and fuzzy rules. In power systems, PMU installation is a difficult task.
Wide-area Fault Location [24]	Its functions include both surveillance and controlling.	For big training data, specialists are required to define the membership function and fuzzy rules. In power systems, PMU installation is a difficult task.
Modal Transform[25]	It is unaffected by electrical parameters or frequency.	The use of modal parameters is essential.
	The three-phase	

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	system provides a simple linear transformation (current and voltages are identical).	
	The simple multiplication of matrices is used to transpose and non-transpose electrical data. There are no convolution techniques necessary.	For complicated structures, it is unreliable.
Deep Learning[26]	In numerous domains, best effectiveness on challenges that greatly beats other solutions. This isn't a little difference; it's a huge one.	It is necessary to collect a vast amount of data.
	The use of deep learning eliminates necessity feature engineering, which is among the main time-consuming aspects of machine learning.	The training of Deep Learning technique is technologically costly and takes weeks, requiring hundreds of workstations with powerful graphics processing units (GPUs)
	It is an architecture that can be easily changed to new issues, such as time series, languages, and so on, by employing techniques such as convolutional neural networks, recurrent neural networks, long short-term memory, and so on.	DL training technique determination is a dark art with no theory.

4 Comparative Method Analyses:

Much of the approaches that were studied are based on principles, As if the calculated voltage or current were phasor voltage or current, At the station or conversion sites, there is also a current transformer. At least two or three transformers connected towards the ending port of the semi lines or power lines are required for material collection [27]. Transformers at the termination of a distribution networks are a privilege, particularly when high cables become twisted. Current and voltage information were required by several erroneous impedance-based algorithms [28]. The possibility of magnetic core exhaustion is amongst the most significant disadvantages of using a current transformer throughout a sudden accident [29]. Whenever the voltage appears to be no longer persuaded in regard to the second winding and the secondary current is retained next to the zero point, the fluxes remains constant for a duration of time. The quantity of current, specifically on the transformer, as well as the power factor and fundamental relationship X/R, define the time of saturation (period) [30].

5 Observations:

By monitoring and studying several models for transmission line fault prevention, it is discovered that each model does have its own usefulness as well as a few shortcomings that can be integrated at certain levels but cannot be addressed at others. Deep learning is the greatest approach for creating a strategy for protection against faults in transmission lines because it's much more precise than machine learning alone. Although it needs more data to obtain, it can provide the most accurate results. Furthermore, the application of Artificial Intelligence in the process can produce alternative predictions that can be further analysed in such a manner that a breakdown in transmission lines can be detected before it occurs.

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Nowadays, technological innovation is involved in every sector, so everything is virtualized and software-based, so it is suggested that AI and Internet of Things IoTs be tied with the power sector in order to assess different relays in full compliance with loading patterns during the day and retain logs accordingly. Second, it should be designed to support High Voltage DC HVDC transmissions.

6 Conclusions:

The effectiveness of almost any fault estimate approach is dependent on not just the application domain, but too on calculation interval and converges in a complicated multi-terminal system. With some more features and much more complicated processing, time inference grows. As a result, fault assessment must be done adaptively so that relaying techniques can provide an abrupt trip signal to counteract a fast rising dc fault. This objective results in the development of grid side networks that are efficacious of functionality, versatility, and efficiency.

Secondly, power quality is a component that may have an impact on the research since such positive sequence may alter as a result of nonlinear installations of equipment in grid stations, such as solid state relays.

7 List of abbreviations:

SPM: - Synchronized Phasor Measurements

SCADA: - Supervisory Control and Data Acquisition

PMU: - Phasor Measurement Unit

NI: - National Instruments

SDI: - Standard Deviation Index

AI: - Artificial Intelligence

ML: - Machine Learning

AA: - Adaptive Auto - reclosing

FLI: - Faulted Line Identification

HVDC: - High Voltage DC

GPUs: - Graphics Processing Units

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