International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 917-943 www.ijaem.net ISSN: 2395-5252

The Conventional Distance Protection scheme for 132 kV Transmission lines – A Review

[1]Simon Ejededawe Igberaese,[2]Jacob Tsado,[2]Jonathan Gana Kolo&[2]Umar Suleiman Dauda

[2]Federal University of Technology, Minna, Niger State, Nigeria.
[1]Federal Polytechnic, Auchi, Edo State, Nigeria.
Corresponding Author: Simon Ejededawe Igberaese

Date of Submission: 09-03-2023 Date of Acceptance: 18-03-2023

ABSTRACT
The conventional distance protection scheme in Nigeria is gradually becoming unreliable to handle the diverse distance relay trips due to its inability to protect the zones of protection (zone one, zone two and zone three) for 132kV transmission lines generally. This inability to protect the zones of protection is caused by some negative influences that affect the Distance Relay (D.R.). The D.R. is used to protect transmission network by comparing the apparent fault impedance with the D.R setting impedance (actual impedance). But, the apparent fault impedance may differ from the actual impedance due to some network challenges such as the effects of load resistance, arc fault resistance, series capacitor, power swing condition, in-feed current, load encroachment issues, and mutual coupling for double or parallel transmission lines. These network challenges contribute to false trips and results to under-reach or over-reach errors in the actual impedance measurements. In modern transmission line networks, two or more of these challenges can happen at the same time. It may be difficult to tackle these challenges but, the proper setting of the D.R would result to a more suitable value that can adapt to these unpredicted challenges that may occur in transmission networks. This research has carried out a review on some of the challenges as it relates to distance protection scheme. Such challenges ranged from the fault (Arc) resistance impact, remote in-feed current flow outlets, load encroachment condition and mutual coupling impediment affect the double-ended or parallel 132 kV transmission lines. At the end of the review, it was observed that the difficulties and restrictions of the numerous methods used were based on their mal-operational characteristics exhibited by the conventional distance relays in transmission line protection. This review presents the research gaps as it relates to the influence of arc (fault) resistance on the output impedance of the distance relay; the impact of in-feed current flow from intermediate or remote sources into the protected zone; the impact of mutual inductive coupling between conductors due to the presence of the zero sequence current component, I_0 in the zero sequence impedance path and the influence of peak load conditions (loadability effect) when a double or parallel transmission line is overloaded , which subsequently trips the line to be out of service. However, it is the interest of the researcher to address these hitches in the near future by exploiting practicable solutions, which is the essence of this research.

KEYWORDS: distance protection, distance relay, false tripping, fault resistance, load resistance, fault impedance etc.

I. INTRODUCTION

The distance protection scheme is normally applied to protect transmission lines. It acts as the main protection for overhead transmission lines. It functions as a standby (backup) protection to the linking parts of the network such as bus bars, generators, transformers, motors and feeder lines. However, distance protection schemes havebeen considered an indispensable alternative for transmission networks due to its benefit when compared to the over-current and differential protection schemes due to its higher sensitivity, selectivity and precision in operating characteristics [16]. Distance protection is faster and more selective than over-current protection. It is also less prone to fluctuations in the power system conditions. An additional benefit of the distance protection is that it can adapt easily to a unit protection scheme when applied with a communication connection [86,24]. A distance relay controls the impedance of the faulted portion of a transmission line from the measured voltages and currents at the relay location. When the measured fault impedance is compared with the impedance of the transmission line to be protected, one can determine if a fault exists on the transmission line between the relay and the fault point or not [38]. If the measured fault impedance becomes smaller than the impedance of the transmission line, it means that a fault exists on the transmission line between the relay and the fault point (vice-versa). This suggests that the distance protection scheme could reach a protection decision with impedance measured between fault point and the relay location [63,13]. [45]mentioned that the protection of any system or network is carried out through unique protective and automation equipment that are technologically based. [45]specified that the continuity of electricity supply to consumers was guaranteed through standard automation techniques. [45]added that achieving a distinct protection scheme would be possible through an integration of modern interconnected elements leading to high decision making and faster tripping time of the relay during fault condition.

II. JUSTIFICATION OF THE RESEARCH

The distance protection technique is immensely growing towards being adaptive in terms of operational proficiency in adjusting to system conditions and characteristics. Hence, this is necessary for the power system to vary its protection settings in real-time according to the system operating states and conditions [43].[55]stated that the power transmission system helps in the transfer of bulk power through transmission lines to end users. The power transferred experiences depreciation due to fault conditions, Hence, the need to protect the transmission lines cannot be over-emphasized. This is because majority of the power system faults occur in transmission lines. Research on more recent emerging technologies or techniques in the field of distance protection scheme is ever-growing Researchers in this field are working daily towards a integrated and self-healing (adaptive) capability intended to deliver a reliable and quality power in a naturally friendly manner [43]. A lot has been researched over the years with various protection techniques being identified though some are still ongoing [43].[3]proposed a technique that utilized local relay data to improve the security of zone 3 distance protection for transmission lines experiencing enormous cascading events, which results to black out. [61]suggested that the gradual migration from the conventional grid system to a non-conventional technology necessitates an adaptive fault monitoring system capable of protecting the power system. The transmission lines connecting the Irrua 132 kV, Etsako 132 kV, Okpilla 132 kV, Oghara-Delta 132 kV and the Amukpe-Sapele 132 kV transmission lines were overloaded and were prone to false tripping conditions due to D.R. mal-operations [79].

III. STATE OF THE ART ON DISTANCE PROTECTION SCHEME

In modern times, conventional transmission networks have tried to bring a lasting solution to the different challenges that greatly affect the superiority and reliability of service from the transmission stations or substations [32]. The major issue associated with the conventional protection scheme is the relay coordination problems due to changes in the grid configuration, changes in fault types and false tripping complications [66]. However, the negative impact of the aforementioned factors has resulted to increasing the complexity of the power transmission system with numerous operational problems [66,82]. Literatures have proposed protection strategies in a bid to solving some of these problems like the under-reaching or over-reaching issues, by adjusting the conventional distance relays in order to improve the performance in transmission and distribution systems [5,47]. However, the main problems with distance protection scheme when in operation mode are; the in-feed effect, fault resistance effect, directional relay characteristic, under-reaching or over-reaching conditions affecting distance protection scheme [59]. The active or true impedance of the conventional distance protection scheme resulted in erroneous fault detection due to its inability to adapt to fault situations by distorting adequate protection possibilities [59]. Another factor that was considered was the unbalanced (unsymmetrical) faults, which had negative impact on the reliability and speed of the distance protection scheme [40]. In addition, different approaches were used to define voltage drop magnitude and voltage amplitude evaluation according to [51] and [47,48] respectively. Other schemes had to deal with more specific complications such as fault direction determination [19] and protection challenges related to the point of interconnection according to [23] and [82].

[31]proposed an accurate non-pilot scheme for the faster trip of distance relay during zone two (2) faults. [31]also mentioned in their research that the adjustment of the zones of protection is a very crucial aspect of distance protection scheme. [65] mentioned that an adaptive reach was required for zone three (3) protection, which was used to synchronize measurements with distance relays.

[69,70] employed the use of a communication system to improve the performance characteristics of relay when enhancing the speed of digital distance protection. [50] engaged a communication system on a field programmable gate array (FPGA) board, which was verified using a PSCAD/EMTDC simulator and COMTRADE 99 communication protocols. The drawback in their research was the use of a communication system, which has contributed to a rise in the operating cost of the network. [41]also employed communication systems based on the IEC 61850 standards. [84]presented the second-order Taylor-Kalman Fourier filter for signal processing analysis, which was faster and was with a smaller signal estimation error. [57] realizedthe tripping range as delimited by straight lines, considering other factors such as disparities of setting distance relay, fault resistance, power factor and measurement errors forming a quadrilateral tripping area. [68]implemented a compensation factor for zero-sequence impedance. Distance relays have been considered to be an essential alternative mostly used in transmission networks [16]. Distance relay setting was dependent on the measured impedance, which was affected by the changes in grid configuration [82] because of the fact that they had higher sensitivity, selectivity, accuracy and its operation was faster when compared to the overcurrent relays [16]. [33]emphasized that the essence of monitoring the transmission line and its parameters such as the resistance, inductance, capacitance and shunt conductance is very necessary for transmission line protection.

TABLE 3:- SUMMARY TABLE FOR STATE OF THE ART ON DISTANCE PROTECTION SCHEME

S/NO	AUTHOR(S)	FINDINGS	LIMITATIONS
1.	[32]	Different challenges that greatly affect the superiority and reliability of service from the transmission stations for conventional distance protection scheme in modern times	Grid configuration changes due to relay operation issues
2.	[66,82]	Co-ordination problems, variations in fault appearances and false tripping hindrances caused the conventional distance relay to mal-operate	Relay operational problems result to false tripping
3.	[66,82]	Under-reaching or over-reaching issues inhibits the operational capability of the conventional distance protection scheme	Inability of the distance relay to enter into theimpedance characteristic boundary of zone 2 and zone 3.
4.	[59]	The active impedance of the conventional distance protection scheme resulted in erroneous fault detection and location with incompetence in adapting to fault conditions thereby distorting adequate protection possibilities	Negative in-feed current influence, fault resistance variation effect, under-reaching or over-reaching issues
5.	[40]	Unbalanced short faults had negative impact on the reliability and promptness of	Inadaptability to varying system conditions due to adaptive protection possibilities
6.	[52, 49]		Under-voltage challenge

		the distance protection scheme in tackling all fault conditions Various approaches were used to define voltage drop magnitude and voltage amplitude	
7.	[65]	An adaptive reach setting was required for zone three (3) protection, which was used to coordinate measurements with distance relays	The adaptive reach setting capability was not captured, which contributed to the problem of zone 3 distance protection mis-operation
8.	[67]	Employed the use of a communication system to improve the performance characteristics of relay	High operating cost of the communication system
9.	[50]	Engaged a communication system on a field programmable gate array (FPGA) board for distance protection	High operating cost of the communication system
10.	[41]	Employed communication systems based on the IEC 61850 standard	The signal speed processing of the communication device according to IEC 61850 was limited
11.	[84]	The second-order Taylor-Kalman-Fourier filter for signal processing analysis, which was faster and was with a smaller signal estimation error	Presence of signal estimation error during signal processing of the Kalman-Fourier filter
12.	[57]	The relay tripping range was defined by straight lines indicating errors in the quadrilateral tripping area	Disparities of setting distance relay, fault resistance, power factor and measurement errors

IV. SHORTCOMINGS ENCOUNTERED IN DISTANCE PROTECTION SCHEME

4.1 FAULT RESISTANCE CHALLENGE

The main issue that caused the malfunctioning of the distance relay when applied to transmission line was initiated by the over-reach errors in impedance estimation due to the high reactance to Resistance (X/R) ratio, which also affected the magnitude of the fault current as stated by [34]. Fault resistance impact results in additional impedance measured by the distance relay. However, this impact may not only cause under-reach problem but also an overreach challenge. The over-reach challenge caused the relay does not identify the fault since the impedance seen by the relay is outside the protection zone [59]. It was stated that the distance relay was unable to eliminate the over-reach problem due to the presence of high impedance and high arcing resistance [4]. The high arc resistance made the conventional distance relay to face hitches in recognizing fault current on the current path of the transmission line. Its inability to recognize fault current in the current conducting path was due high arc resistance, which is a high restriction or opposition to fault current flow. [2]emphasized that cascading incidences like false line tripping, overloading of lines, mal-functioning of protection system equipment and voltage instability, had various impacts on the conventional distance relay in zone 3 causing an over-reach challenge under heavy load condition or out of service condition during fault was not completely addressed from their research. [4]advocated that the fault which occurred beyond zone one (1) for the conventional distance relay was an over-reaching problem encountered in zone 2 and zone 3. It was stated that the distance relay was unable to eliminate the over-reach problem due to the presence of high impedance and high arcing resistance. The high arc resistance made the conventional distance relay to face hitches in recognizing fault current on the current path of the transmission line. Its inability to recognize fault current in the current conducting path was due high arc resistance, which is a high restriction or opposition to fault current flow. [7]mentioned that the influence of mutual coupling on the zero sequence current was substantial because it induced a fault voltage into the protected line. This made the impedance measured by the relay to be higher or lower than the actual impedance, which is mainly dependent on the polarity of the induced voltage [7]. [9]presented a zone one (1) distance relaying algorithm for single-line to ground (SLG) fault in long parallel transmission lines. They specified that the distance protection scheme that was based on the series impedance line model with a negligible shunt capacitance and propagation effects. But, it was observed that the fault (arc) resistance was considered as a non-negligible factor that influenced the conventional distance relay during ground faults. The fault (arc) resistance effect made the distance relay not to trip (mal-operation) due to the fluctuation of the apparent impedance of the transmission line. This is a limitation in this research. [10]specified in their research that single-phase faults that occurred in distance protection scheme were highly resistive faults. [10,12] itemized that the conventional distance protection scheme was almost defective due to fault (arc) resistance influence on ground fault conditions. This resulted to a drop in voltage across the arc position. This influenced the fault (arc) resistance to be high thereby caused delayed trips to occur on the conventional distance relay. This is a constraint in this research. [12]indicated that the mho relay used for long transmission line had an under-reach problem due to fault (arc) resistance influence on the conventional distance relay. Longer tripping time of the distance relay resulted to fault resistance influence on the distance relay. This is a limitation on its own. [18]proposed an approach of protective relaying method used for detecting faults at various locations in a long transmission line. The proposed approach was affected by fault resistance and fault inception angle, which have been studied. The approach only performed reasonably for internal faults only but had limitation in terms of considerations on external faults location. They concluded that response to external fault conditions was only useful during coordination delay in distance protection scheme. [39] acknowledged that for distance relays, the apparent positive-sequence impedance measured was directly proportional to the fault distance, which could be estimated for each fault type. The estimation of the fault location was affected by high fault resistance for ground faults. Hence, the fault resistance introduced an error, which served as an opposition to the fault distance estimation measurement. This error made the apparent impedance measured by the relay to no longer be proportional to the distance between the relay and the faultlocation[39]. The fault resistance affects the loads on the transmission line resulting to fault location errors. This research did not reveal the non-proportionality situation between apparent impedance and the distance of the transmission line. [48,49] suggested a distance protection method based on voltage amplitude evaluation used to decrease the fault resistance complications by using the fault-point voltage, measured current and setting impedance to create a virtual measured voltage. This method recognized the in-zone and out-of-zone faults from other types of faults by comparing the original amplitudes. [53]declared that cases of high fault resistance associated with single line to ground faults caused high fault impedance resulting to over-reaching or under-reaching problems dependent on the forward or reverse directions. The magnitude of fault resistance effect experienced on the transmission line was not determined. This was recognized as a research gap. [74] confirmed that the distance relay was the main equipment for the protection of power transmission lines as it measures the impedance between relay and the fault point. They

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 917-943 www.ijaem.net ISSN: 2395-5252

also captured in their research that the fault resistance influence on the distance relay characteristic during ground faults depreciated the reliability of distance protection algorithms. The quadrilateral characteristic of the relay in distance protection was implemented for the protection of a 220 kV Algerian transmission line network using Matlab/Simulink environment. The performance of quadrilateral characteristic was evaluated for different fault locations with different fault resistances assigned to both single and double phase faults. The change in fault resistance effect affects the performance of the distance relay greatly. According to the researchers, the results obtained for low fault resistances were realistic as they indicated. However, the results for high fault resistances were not feasible for implementation. This becomes a drawback of this research and it calls for more attention in the investigation on the impact of high fault resistance on distance protection scheme. [83]mentioned that the problems of relay setting were based on the fault resistance changes in distance protection scheme. They observed that the conventional distance protection scheme had errors due to fault resistance changes. The errors were not completely taken care of and the assumptions made in terms of fixed parameter settings were not clearly stated in their research. The limitation of their research was that the conventional distance protection scheme mentioned due to the fault resistance changes needs to be addressed.

TABLE 4.1:- SUMMARY TABLE FOR FAULT RESISTANCE CHALLENGE

S/NO	AUTHOR(S)	FINDINGS	LIMITATIONS
1.	[34]	The distance relay malfunctioned when applied to transmission line due to the high reactance to Resistance (X/R) ratio, which affected the magnitude of the fault current	Over-reach errors in the impedance estimation
2.	[59]	Fault resistance impact resulted in additional impedance measured by the distance relay. The impact may not only cause under-reach problem but overreach challenge	The over-reach challenge caused the relay not identify the fault since the impedance seen by the relay is outside its protection zone
3.	[4]		Presence of high impedance and high arcing resistance on the distant transmission lines.
4.	[2]	The fault that occurred beyond zone one relay was an over-reaching problem, which was present in zone 2 and zone 3. The distance relay was unable to eliminate the over-reach problem	False line tripping, overloading of lines, mal-functioning of protection system equipment and voltage instability
5.	[7]		The polarity of the induced voltage caused the high impedance measurement by the distance
6.	[9]	Cascading events had various impacts on the conventional distance relay in zone 3 causing an over-reach challenge under heavy load condition or out of service condition during fault	Fault (arc) resistance made the distance relay not to trip (mal-operation) due to the fluctuation of the apparent impedance of the transmission line

		The influence of mutual coupling on the zero sequence current was significant because it induced a fault voltage into the protected line. The distance protection scheme was based on the series impedance line model with a negligible shunt capacitance and propagation effects.	
7.	[10]	The single-phase faults that occurred in distance protection scheme were highly resistive faults.	The conventional distance protection scheme was defective due to fault (arc) resistance influence on ground fault conditions
8.	[12]	The mho relay used for long transmission line had an under-reach problem due to fault (arc) resistance influence on the conventional distance relay	Longer tripping time of the distance relay resulted to fault resistance effect on the distance relay
9.	[18]	An approach proposed for protective relaying was used to detect faults	The approach only performed reasonably for internal faults only but had limitation in terms of considerations on external faults location
10.	[39]	The estimation of the	The fault resistance introduced an error in opposition to the fault distance measurement and the non-proportionality of the relay's apparent impedance to the distance between the relay and the fault

11.	[48, 49]	fault location was affected by high fault resistance for ground faults	location The distance protection method for in-zone and out-of-zone faults only captured other types of faults except single-phase faults
12.	[53]	The distance protection method recognized in-zone and out-of-zone faults for all other types of faults using the fault-point voltage, measured current and setting impedance	Over-reaching or under-reaching problems. The magnitude of fault resistance experienced on the transmission line was not determined
13.	[74]	High fault resistance associated with single line to ground faults caused high fault impedance	The fault resistance influence on the distance relay characteristic during ground faults depreciated the reliability of distance protection scheme. The results obtained for high fault resistances in their research were not feasible for implementation.
14.	[83]	The distance relay was the main equipment for the protection of power transmission lines as it measures the impedance between relay and the fault point.	The conventional distance protection scheme had errors due to fault resistance changes
		The problems of relay setting were based on the fault resistance changes in distance protection scheme	

4.2 IN-FEED CURRENT CHALLENGE

In the case of intermediate sources, the in-feed current effect is the main influence for distance protection scheme because it affects the measured impedance. This problem caused under-reach error because the distance relay does not measure the all the fault current in the network [34]. [14] stated that intermediate in-feed current from various sources is present between the relay location and fault point. They mentioned that the in-feed current from various outlets will be injected to the fault point with a higher voltage magnitude and subsequently, the voltage measured at the relay point will be higher than the normal voltage. Hence, the relay will see an impedance value higher than the actual impedance value. Hence, the distance relay will deduce that the fault is at a higher time-graded zone and unnecessary tripping of relay will be introduced or the relay may not trip at all. The existence of intermediate in-feed from various sources or outlets caused the relay's reach ability issues in the distance protection scheme [36]. This issue has been recognized in the case of transmission line protection as a challenge. Usually, zone one as the 'zone of under-reach' was set without considering the presence of in-feed, while zones 2 and 3 are taken as the 'zones of over-reach' and they were set considering all in-feeds [36]. Hence, these reach ability issues reduced the loading limit of the relays by causing them to be less selective in their operations [36]. This challenge was not addressed. [54]recommended a method using phasor measurement unit (PMU) based zone settings of distance relay for protection of multi-terminal transmission lines. The method used current coefficients to adjust the zone settings of the relays during in-feed current flow. The current coefficients were computed by using the phasor data concentrator at system protection center (SPC) with current phasor obtained from the PMU. The operation of the distance relays during in-feed current flow was demonstrated with a four-bus model in PSCAD/EMTDC environment. The zone settings of the distance relay during in-feed current flow did not present the results of the implemented four-bus model and the phasor data concentrator at different fault conditions. [80] stated that the effects of the remote in-feed and arc resistance on the distance relay settings coordination for IEEE 9-bus system. The approach included the effects on the setting using four zones quadrilateral characteristics. Overlap and under reach issues had been raised concerning zone 2 and zone 3 protections, which were due to the remote in-feed current and high arc resistance effects caused by earth faults. The dual problems mentioned had no better solutions highlighted in their research. So, further collaborative research needs to be carried out in this regard.

TABLE 4.2:- SUMMARY TABLE FOR IN-FEED CURRENT CHALLENGE

S/NO	AUTHOR(S)	FINDINGS	LIMITATIONS
1.	[34]	In-feed current flow from intermediate and external sources influence the distance relay to mal-operate	under-reach errors in the impedance estimation due to in-feed current influx
2.	[14]		In-feed currents from various outlets inject a higher voltage magnitude at the fault compared to the normal voltage point
3.	[36]	intermediate in-feed current flow from various sources is present between the relay location and fault point	Unnecessary tripping of relay was introduced or the relay may not trip at all due to under-reach or over-reach conditions
4.	[54]	the distance relay deduce faults at higher time-graded zones of the distance protection scheme. The intermediate in-feed from various sources or outlets caused the relay's reach ability issues in the distance protection scheme	The zone settings of the distance relay during in-feed current flow did not present the results of the implemented four-bus model and the phasor data concentrator at different fault conditions.
5.	[80]		Overlap and under reach issues had been raised concerning zone 2 and zone 3 protections during the relay caused remote in-feed current and high arc resistance into the protected zone

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 917-943 www.ijaem.net ISSN: 2395-5252

	a phasor measurement unit (PMU) based zone settings of distance relay for protection of multi-terminal transmission lines by using a four-bus model to demonstrate in-feed current flow and current coefficients to adjust the zone settings of the relays during in-feed current condition	
	The effects of the remote in-feed and arc resistance on the distance relay settings coordination for IEEE 9-bus system as well as the effects on the setting using four zones quadrilateral characteristics were indicated	

4.3 MUTUAL COUPLING COMPLICATION

The case of the zero-sequence compensation factor (K_0) for the correct operation of distance protection scheme during Single Line to Ground (SLG) faults was considered by [68] for zero-sequence impedance. In this case, the impedance measured by the ground distance relay due to the zero sequence impedance, Z_o effect was different from the positive sequence impedance measured to the fault position [68].During phase to ground faults, a zero sequence component of current can introduced an error on the phase to ground impedance measured by the distance relay for double circuit or parallel transmission line [7]. [17] emphasized that mutual coupling on parallel transmission lines had adverse impact on the reliability and security of power protection schemes. They specified that there had been inadequate research on estimating the magnitude of adverse impact of mutual inductive coupling during fault conditions. The shortcomings associated with conventional ground distance elements in the presence of mutual coupling could militate against the distance relay performance. The mutual inductive coupling current could induce voltage into the protected line, which made the distance relay to mal-operate on the protected line. [77] presented that the mutual coupling effect was caused by the induction of zerosequence current and voltages into the double circuit transmission lines. The zero-sequence voltage is a voltage drop produced by zero-sequence current flowing through the double circuit transmission network. The zero-sequence voltage is highest at the fault point and normally decreases as it gets closer to the sources of the ground current. Strong zero-sequence current buses having low zero-sequence shunt impedances to the neutral bus had very small zero-sequence voltage during ground faults. In addition, zero-sequence mutual coupling induces a voltage rise in the zero-sequence network causing a zero-sequence voltage reversal. [81] itemized that the conventional distance protection scheme had some problems especially when protecting a three-terminal mutually coupled transmission line. They indicated that during an in-feed condition of a three-terminalmutually coupled transmission line had an over-reach problem. This affected zone two and zone three of the distance protection because it made the distance relay at the zones of protection not to work properly. Thus, it was concluded that there was error between the measured source impedance and actual fault impedance of the transmission line.

TABLE 4.3:- SUMMARY TABLE FOR MUTUAL COUPLING COMPLICATION

S/NO	AUTHOR(S)	FINDINGS	LIMITATIONS
1.	[68]	the zero-sequence compensation factor (K_0) for zero-sequence impedance was needed for correct operation of distance protection scheme during Single Line to Ground (SLG) faults	the zero sequence impedance affect the mutual coupling inductive voltage by causing an error for different positive sequence impedance measured
2.	[7]	During phase to ground fault, phase to ground impedance was measured by the distance relay for the double circuit transmission line	During the phase to ground fault, a zero sequence component of current introduced an error for the double circuit transmission line
3.	[17]	Mutual coupling on parallel transmission lines had adverse impact on the reliability and security of power protection schemes	The mutual inductive coupling current could induce voltage into the protected line and inadequate research on estimating the magnitude of adverse impact of mutual inductive coupling during fault conditions
4.	[77]	the mutual inductive coupling (zerosequence) current induce voltage into the protected line of the double circuit transmission line	the induction of zerosequence current caused the zero-sequence voltage to experience voltage drop in the double circuit transmission line
5.	[81]	The presence of third source-terminal caused under reach problem for the transmission line faults beyond the tap point. An in-feed condition for a three-terminalmutually coupled transmission line had an over-reach problem	There was error between the measured source impedance and actual fault impedance of the transmission line. The error made in-feed current to flow from other sources into the protection zones

4.4 LOAD ENCROACHMENT PROBLEM

[58] specified in their research that the inaccuracies in distance measurement resulting to measurement errors and inaccuracies in line impedance measurement. The challenges affect the operation of the distance relay in the determination of the measured apparent impedance resulting to an inaccurate fault location [58]. The inaccurate apparent impedance determination was as result of arc fault resistance due to ground faults and also the injection of remote in-feed currents from the remote multi-terminal sources into the distance protection zone was seen as an encroachment issue. [78] explained the dynamic loading effect on different types of distance relay characteristics and the relay loadability limits at different power factor angles. It was revealed in their research that the load power of the transmission line was very enormous to the extent that it reduced the load impedance, which made the load to intrude into the relay's characteristic boundary. The encroachment of the load made the distance relay to perceive a fault condition and consequently trips the line to be out of service. This is a constraint because a heavily loaded line has been taken out of service without a real fault existing on the transmission line.

TABLE 4.4:- SUMMARY TABLE FOR LOAD ENCROACHMENT PROBLEM

S/NO	AUTHOR(S)	FINDINGS	LIMITATIONS
1.	[58]	The inaccuracies in line impedance distance measurement affect the operation of the distance relay in the determination of the measured apparent impedance	It results to line impedance distance measurement errors
2.	[78]	The dynamic loading effect on different types of distance relay characteristics and the relay loadability limits at different power factor angles	A large load power on the transmission line reduced the load impedance causing the relay to intrude into its characteristic boundary

V. NUMEROUS TECHNIQUES USED FOR DISTANCE PROTECTION SCHEME

[6]proposed the hybridization of two robots into a single robot with an enhanced model committed to monitoring transmission lines. The main inspection functions of the robots are climbing and flying along the transmission lines. The research had its drawbacks, which were stated as: poor battery capacity, electromagnetic shielding and advanced control for uncertainties such as winddisturbances. [20]captured the use of data and commands to program robot through the offline computer with robotic sensors sending feedback as data from accurate positions. The robotic components were assembled and placed on the transmission line to diagnose fault conditions. The use of inspection robots in transmission line monitoring has helped in checks against mechanical damage to reduce cost in terms of outages and human wastage due to fault conditions. [19] suggested a distance relay based on Resistance-Inductance (R-L) differential equation algorithm which was used to determine the directional problems encountered when zero voltage faults occured. [21]presented an Artificial Intelligence (AI) technique for distance protection for transmission lines. [25] proposed an intelligent protection scheme, which was hindered by the installation of expensive fault current limiters. The protection scheme was designed with communication abilities for smart cascading switching action with supervisory protection algorithm in the conventional distance protection scheme. It experienced failure in fault clearance, which was due to high fault current value when compared to the breaking capacity of the circuit breaker. The limitation of this research was that the proposed scheme had a high fault current due to the high resistive fault condition. Also, the high implementation cost of connecting intelligent devices to the transmission line is also a limitation. [26]proposed a new built-in adaptive load compensation algorithm for the distance protection zones during line-to-ground faults on heavily loaded power lines. The drawback of this research was that the performance metrics on the adaptive compensation algorithm for peak load lines was not clearly stated in their research. This was taken as a shortcoming. [27] employed the use of phase voltage and current parameters on the NeuralNetwork toolbox of MATLAB software. [27]indicated that there was an average and the maximum error percentages at the neural network output after the training of the network. This error was due to inconsistencies in the parameter estimation used by the distance relay as input for the training. The performance metric of the NeuralNetwork was not clearly established. [28] revealed an adaptive technique for the synchronization of zone 2 operation using MATLAB software. The technique was used to adjust the zone 2 protection due to the sudden changes in the grid voltage and current parameters.The integration of wind farm to the Alternating Current (AC) grid resulted to the false trip of the distance relay at a fixed fault resistance. The researchers recommended that the arc resistance be recommended for further studies when considering the changes in the wind speed when transmitting power from the wind farm to the AC grid. [30] proposed a techniquebased on the hybrid distance and differential protection schemes. The proposed technique was able to detect the fault location similar to distance relay using voltage and

current parameters at both ends of the transmission line. The active power at both ends of the transmission line was calculated with the high fault resistance inclusive. The fault resistances calculated was directly deducted from the calculated impedances of the relays. In this technique, the trip boundaries of the relays were used to ascertain the exact location of the fault and its distances from the relay point. The differential protection scheme mentioned was not dependent on the impedance of the transmission line.[29] demonstrated the effects of static synchronous series compensation (SSSC) and series capacitive compensation (SCC) as two series compensators for the distance protection using theoretical and computational methods. The effects of the two types of series compensators; the Static Synchronous Series Compensation (SSSC) and Static Capacitive Compensator (SCC) on the impedance measured by the distance relays begun with the use of a Phasor Measurement Unit (PMU). The PMU based technique was used to measure and transmit signals to the relays throughcommunication channels at both terminals of the series compensators.[87]proposed fault monitoring method used as alternative monitoring module of the power grid. The module was used to classify and detect faults in a transmission line. This was achieved by using PMU to study the equivalent power factor angle (EPFA) variation when identifying a fault in the network. [7]presented a review for distance protection of series compensated lines and its peculiar problems. It was observed that the developments in this area were largely concentrated on voltage drop estimation across the capacitor bank, phasor estimation and co-ordinated protection scheme. They highlighted that series capacitors in transmission lines could cause current reversal, voltage reversal and sub-synchronous fluctuation problems in distance protection scheme. They stated that distance protection scheme experienced inherent delay in the time required to compute the phasor quantities from voltage and current signals. The techniques used were limited to the phasor estimation computation, which caused delay in operation. [42]captured that artificial neural network technique was used to detect and identify fault in power transmission lines. They also stated that fault resistance could affect the measured impedance of the relay by causing a proportional increment in the abnormal relay impedance. It therefore implies that fault resistance will always increase proportionately with the abnormal impedance of the relay. [46]used the Phasor Measurement Unit (PMU) technique to produce harmonized measurement of real-time phasor of voltage and current in transmission lines accomplished by sampling voltage and current waveform using timing signals from global positioning system (GPS) satellite. The PMU delivers the real-time magnitude and phase angle of the transmission system. [51]proposed an adaptive distance protection scheme based on the impedance complex plane method utilized for the phase relationship between the negative sequence current at the relaying point and the current at the fault point. As indicated in their research, the proposed adaptive distance protection scheme was not immune to the changes in the fault resistance parameter during ground faults scenerio, that is, the changes in the fault resistance can greatly affect the distance protection scheme. This was taken as a research gap. [52]proposed an adaptive distance protection scheme to handle the sensitivity and selectivity problems in DFIG (doubly-fed induction generator) wind farm collector transmission line protection. On this basis, an adaptive distance protection criterion was formed according to the phase relationship between the fault current and the measured current. The proposed method at different operational modes was affected by the weak in-feed current characteristics of the wind generator collector system in the wind farm. The wind generator experienced an in-feed current flow from the DFIG (doubly-fed induction generator) wind farm collector, which was recognized as a research gap. [56]presented both past and present developments of distance protection scheme and its implementation techniques. The researchers specified that the consequence of power swing challenges caused a rapid change in the impedance vector characteristic by varying the power impedance measurement of the transmission line. The disparity in the power impedance measurement affects the fault resistance influence on the distance relay during fault conditions in a transmission line. [60]offered a relay settings re-calibration technique, which was used to provide solution to the numerous issues encountered through the use of conventional settings of the relay at theShiroro-Abuja 330 kV transmission line. He suggested a protection algorithm based on effective relays coordination so as to reduce relay operating time thereby minimizing damage to equipment and personnel. Runge-Kutta method was used to adjust the parameters such as Plug Setting multiplier (PSM) and Time Setting Multiplier (TSM) to get the optimum relay coordination for relay setting. [62] focused on the conventional relay co-ordination technique in power protection system. The conventional relay co-ordination technique was limited due to the relay's conventional method of co-ordination because of the complexity of the power protection system and the necessity of working on a large number of relays made it difficult for the conventional relay co-ordination technique to completely profound solutions to the numerous challenges of distance protection scheme. For this reason, it was recommended by the researchers that research should be prioritized in this regard. Holistically, more sophisticated and intelligent techniques of handling the conventional relay co-ordination complications should be harnessed for power system protection. [64]conducted a hybrid method, machine learning, deep learning and fuzzy techniques were used for the fault classification methods. [71]discussed diversetechniques such as the index-based optimization, Wide Area Monitoring Systems (WAMS), Equal Area Criteria (EAC) and Machine Learning (ML) used for the implementation of the Special Integrity Power System (SIPS). It was observed that most of the suggested SIPS techniques were used in the implementing the improvement in transient stability. The preferred solution for implementing the SIPS by the researchers was load shedding technique. It was found that transient stability of the dominant areas where most of the SIPS were applied was not feasible. Hence, some future perspectives for SIPS were discussed especially on how to implement the integrity protection schemes. Apart from load shedding, other SIPS implementation techniques were not mentioned. So, integrating SIPS implementation techniques and Artificial Intelligence (AI) technique to distance protection scheme would be of great benefit to Special Integrity Power System (SIPS) implementation, which has not been realized. [75]acknowledged that a hybrid Wavelet –APSO –ANN based protection technique was used for protecting a six-phase transmission line. [76]projected the different techniques for relay protection coordination for both transmission and distribution systems. The protection based techniques used to resolve the relay coordination problems, which were expressed as linear and non-linear optimization problems, which could be determined using different optimization techniques such as exact method and artificial intelligence optimization method. The linear optimization problem could be resolved using the exact method as stated by the researchers but the strategy for resolving the non-linear optimization problems was not clearly stated. [85]presented a distance protection method used to enhance impedance measurements using residual voltage compensation to detect and locate all types of fault, mostly for Single Line to Ground (SLG)faults.

TABLE 5:- SUMMARY TABLE FOR NUMEROUS TECHNIQUES USED FOR DISTANCE PROTECTION SCHEME

S/NO	AUTHOR(S)	FINDINGS	LIMITATIONS
1.	[6]	They proposed the hybridization of two robots into a single robot with an enhanced model committed to monitoring transmission lines	Poor battery capacity, electromagnetic shielding and advanced control for uncertainties such as winddisturbances.
2.	[20]		The use of inspection robots in transmission line monitoring has not been completely implemented to checks against mechanical damage
3.	[19]	They captured the use of data and commands to program robot through the offline computer with robotic sensors sending feedback as data from accurate positions. The use of inspection robots in transmission line monitoring has helped to reduce cost	directional problems are usually encountered when zero voltage faults occur
4.	[21]		Requires large volume of data and the presence of costly sophisticated communication devices for fault clearance

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 917-943 www.ijaem.net ISSN: 2395-5252

5.	[25]	in terms of outages and human wastage due to fault conditions.	It experienced failure in fault clearance, which was due to high fault current value. Also, the high implementation cost of connecting the intelligent protection devices to the transmission line.
		A distance relay based on Resistance-Inductance (R-L) differential equation algorithm was used	The performance metrics on the adaptive compensation algorithm for peak load lines was not clearly stated in their research
6.	[26]	Artificial Intelligence (AI) technique for distance protection of transmission lines was proposed	
		They proposed an intelligent protection scheme, which was hindered by the installation of expensive fault current limiters. The protection scheme was designed with communication abilities for smart cascading switching action with supervisory protection algorithm in the conventional distance protection scheme.	
		They proposed a new built-in adaptive load compensation algorithm for the distance protection zones during line-to-ground faults on heavily loaded power lines	
7.	[27]	They employed the use of MATLAB software to estimate the phase voltage and current parameters on the NeuralNetwork	Presence of average and maximum error percentages at the neural network output after the training of the network. Inconsistencies in the parameter estimation used by the distance relay as input for the training

8.	[28]		The sudden changes in the grid‘s voltage and current parameters caused the changes in the fault or arcing resistance during faults
9.	[29]	An adaptive technique for the synchronization of zone 2 operation was revealed. The technique was used to adjust the zone 2 protection due to the sudden changes in the grid voltage and current parameter	the trip boundaries of the relays were used to ascertain the exact location of the fault and its distances from the relay point, which was not a practicable method
10.	[30]	a techniquebased on the hybrid distance and differential protection schemes was used to detect the fault location	The Static Synchronous Series Compensation (SSSC) and Static Capacitive Compensator (SCC) on the impedance measurement by the distance relays had their drawback when used with Phasor Measurement Unit (PMU) Phasor Measurement Unit used to study the equivalent power factor angle (EPFA) experienced difficulty when identifying a fault in a network
11.	[87]	The PMU based technique was used to measure and transmit signals to the relays throughcommunication channels at both terminals of the series compensators	Series capacitors in transmission lines caused current reversal, voltage reversal and sub-synchronous fluctuation problems in distance protection scheme
12.	[7]		performs poorly with data scarcity and cannot converge with little iterations
13.	[42]	They proposed a fault monitoring method used as alternative monitoring module of the power grid. The module was used to classify and detect faults in a transmission line	Delay in the PMU to harmonize measurement is mainly dependent on network availability
14.	[46]		The adaptive setting for the relay co-ordination was not captured in their research
15.	[51]	They presented a review for distance protection of series compensated lines and its peculiar problems. It was observed that the developments in this	Sensitivity and selectivity problems of the adaptive distance relay became a challenge

16.	[52]	area were largely concentrated on voltage drop estimation across the capacitor bank, phasor estimation and co-ordinated protection scheme	The consequence of power swing challenges caused a rapid change in the impedance vector characteristic by varying the power impedance measurement of the transmission line
17.	[56]	Artificial neural network technique was used to detect and identify fault in power transmission lines	The Runge-Kutta method used to adjust the Plug Setting multiplier (PSM) and the Time Setting Multiplier (TSM) does not depict the optimum relay coordination for relay setting
18.	[60]	used the Phasor Measurement Unit (PMU) technique to produce harmonized measurement of real-time phasor of voltage and current parameters using timing signals from global positioning system (GPS) satellite	Limited conventional relay co-ordination, complexity of the power protection system and it requires working with large number of relays Complexity due to data synchronization of the different techniques was being used
19.	[62]		Transient stability of the dominant areas where most of the SIPS were applied was not feasible.
20.	[64]	An adaptive distance protection scheme based on the impedance complex plane method was proposed and utilized for the phase relationship between the negative sequence current at the relaying point and the current at the fault point.	There was large complexity in the hybrid technique used in protecting the six-phase transmission line
21.	[71]		Presence of linear and non-linear optimization problems. The strategy for resolving the non-linear optimization problems was not clearly stated
22.	[75]		The residual voltage compensation method was used to enhance impedance measurements to detect mostly Single Line to Ground (SLG) faults. Other types of fault were unrealistic using the residual voltage compensation method.
23.	[76]	An adaptive distance protection scheme was proposed for the DFIG (doubly-fed induction generator) wind farm collector for transmission line protection	
24.	[85]	Presented both past and present developments of distance protection	

scheme and its implementation techniques.

A relay setting re-calibration technique was used to provide solution to the numerous problems encountered through the use of conventional relay settings on theShiroro-Abuja 330 kV transmission line

They focused on the conventional relay co-ordination technique for power protection system.

They conducted a hybrid method involving machine learning, deep learning and fuzzy techniques, which were used for the fault classification

Special Integrity Power System (SIPS) techniques were used in the implementing the improvement in transient stability

A hybrid Wavelet–APSO–ANN based protection technique was used for protecting a six-phase transmission line

Different techniques for relay protection coordination for both transmission and distribution systems

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 917-943 www.ijaem.net ISSN: 2395-5252

A distance protection method was used to enhance impedance measurements using residual voltage compensation to detect and locate all types of fault, mostly Single Line to Ground (SLG) faults

VI. RESEARCH GAPS IN THE CONVENTIONAL DISTANCE PROTECTION SCHEME

Based on the information gathered from literature search, the review was conducted on available knowledge and research related papers. The following research gaps were discovered in relation to the distance protection scheme. The research gaps are:

(i) Fault resistance due to arcing effect on the overhead transmission caused high impedance, which made the conventional relay to face difficulties in identifying fault current. This fault current is due to the high impedance presence in the current conducting path of the transmission line. The arcing effect is very crucial to the rise or decrease in the apparent impedance of a transmission line. High fault currents are injected into the transmission line from various sources due to the high arc (fault) resistances. The arc (fault) resistance causes the ground distance relay to mal-operate during fault conditions [34],[59],[4],[2],[7],[9], [10], [12], [18], [39], [48, 49], [53], [74]&[83].

(ii) When a fault occurs on a double circuit transmission line outside the distance protected zone, the current(s) from the other line terminal(s) cause an additional voltage across the impedance between the relay and the fault point. For two-terminal applications, the remote in-feed current affects the distance relay voltage only for resistive faults. But, for multi-terminal applications, the remote in-feed current affects the distance relay voltage by causing an additional error function, Z_{ERROR} in the expected apparent impedance output of the distance relay. $Z_{APP} = Z_X + Z_{ERROR}$ where, Z_X is the expected apparent impedance at no fault condition and Z_{APP} is the outcome of the apparent impedance with impedance error added to the normal apparent impedance during fault condition. The effect of remote in-feed current was that the impedance error that flows into the protection zone of relay thereby causing the mal-operation of distance relay. At load condition, the in-feed current flow due to line faults from the remote terminal(s) produced very large apparent impedance called out of phase impedance. The large apparent impedance results in the failure of the ground distance relay to operate (mal-operation of the relay) in adjacent transmission line(s). This was taken as a research gap [34], [14], [36], [54] & [80].

(iii) The mutual coupling that occurs in a parallel or double circuit transmission lines has been studied. It was discovered that there was mutual inductive coupling between the conductors of both lines. The zero sequence impedance path revealed itself as a voltage drop, which was equal to the product of zero sequence current in the adjacent line and the mutual inductance, L. This drop in voltage produces an error on the apparent impedance measurement of the distance relay due to the presence of the zero sequence current component, I_0. The ground distance relaysoverreach (a problem for Zone 1) which occurred when the zero-sequence currents in the protected line and the coupled line flow in opposite directions and the underreach problem (a problem for Zone 2 and Zone 3), which occurred when the currents flow in the same direction. The limitation in the research is the inaccurate reach settings and that of the mutual coupling compensation factor, k_0 which led to the mutual coupling challenge and not providing the distance relay with the necessary information on the actual zero-sequence current flowing in the coupled line can also lead to the mutual coupling challenge [68], [7], [17], [77] & [81].

(iv) Most likely, the effect of peak load conditions on the double or parallel transmission line reduced the apparent impedance seen by the relay to a small value that indicates fault on the line. When a double or parallel transmission lines is overloaded and one of the line is out of service due to the tripping of the line, the load impedance encroaches into the relay's characteristic shape of the next protected zone. The distance relay recognized the encroachment as a fault and subsequently trips the line to be out of service.This was identified as a research gap [58,78].

TABLE 6:-SUMMARYTABLE FORRESEARCH GAPS IN THE CONVENTIONAL DISTANCE PROTECTION SCHEME

REFERENCES		METHODS USED	STRENGTHS	LIMITATIONS/GAPS
1.	[6]	Hybridization approach	Enhanced dual-capacity monitoring model	Poor battery capacity, and winddisturbances.
2.	[20]	Computer Programming Approach	robotic programming with robotic sensors through offline computer	Prone to mechanical damage
3.	[19]	Resistance-Inductance (R-L) differential equation approach	A distance relay based on Resistance-Inductance (R-L) differential equation algorithm was used	directional problems encountered when zero voltage faults occur
4.	[21]	Artificial Intelligence (AI) technique	Intelligence (AI) technique for distance protection of transmission lines was proposed	Requires large volume of data and the presence of costly sophisticated communication devices for fault clearance.
5.	[25]	Intelligent distance protection algorithm	Proposed an intelligent protection scheme	Fault clearance failure, high fault current value., high implementation cost
6.	[26]	Adaptive distance protection algorithm	new built-in adaptive load compensation algorithm for the distance protection zones	The performance metrics on the adaptive compensation algorithm for peak load lines was not clearly stated
7.	[27]	Voltage-Current parameter approach	employed matlab software to estimate the phase voltage and current parameters on the NeuralNetwork	.Inconsistency in parameter estimation used by the distance relay as input for the training
8.	[27]	Parameter synchronization technique	Adjustment of zone 2 grid protection due to the sudden changes in the voltage and	The sudden changes in the grid's voltage and current parameters caused

			current parameters	the changes in the fault or arcing resistance during fault conditions
9.	[29]	Distance-differential approach	A hybrid distance and differential protection technique was used to detect the fault location	The trip boundaries of the relays were used to ascertain the exact location of the fault and its distances from the relay point, which was not a practicable method
10.	[30]	PMU based technique	The technique was used to measure and transmit signals to the relays throughcommunication channels at both terminals of the series compensators	Static Synchronous Series Compensation (SSSC) and Static Capacitive Compensator (SCC) on impedance measurement had its drawback when used with Phasor Measurement Unit (PMU)
11.	[87]	fault monitoring module method	The module was used to classify and detect faults in a transmission line	PMU used to study the equivalent power factor angle (EPFA) experienced difficulty when identifying a fault in a network
12.	[7]	co-ordinated protection approach	developments in this field were largely concentrated on voltage drop estimation	current reversal, voltage reversal and sub-synchronous fluctuation problems
13.	[42]	Artificial neural network technique	used to detect and identify fault in power transmission lines	performs poorly with data scarcity and cannot converge with little iterations
14.	[46]	Phasor Measurement Unit (PMU) technique	Produced harmonized measurement of real-time phasor of voltage and current parameters from global positioning system (GPS) satellite	Delay in the PMU to harmonizing measurement dependent on network availability
15.	[51]	impedance complex plane method	proposed the phase relationship between	relay co-ordination was not captured in

			the negative sequence current at the relaying point and the current at the fault point.	their research
16.	[52]	adaptive distance protection method	proposed for the DFIG (doubly-fed induction generator) wind farm collector for transmission line protection	Sensitivity and selectivity problems of the adaptive distance relay became a challenge
17.	[56]	distance protection scheme	developments of distance protection scheme and its implementation techniques	a rapid change in the impedance vector characteristic by varying the power impedance measurement of the transmission line
18.	[60]	relay setting re-calibration technique	Runge-Kutta method used to adjust the Plug Setting multiplier (PSM) and the Time Setting Multiplier (TSM)	optimum relay coordination for relay setting
19.	[62]	conventional relay co-ordination technique	They focused on the conventional relay co-ordination technique for power protection system	Limited conventional relay co-ordination, complexity of the power protection system
20.	[64]	hybrid machine learning method	Used machine learning, deep learning and fuzzy techniques	Complexity due to data synchronization of the different techniques being used

VII. CONCLUSION

This review has presented some of the recent protection approaches based on the implementation of distance relay in transmission system. The various trends in distance protection scheme for transmission lines are revealed in this review. Hence, the focal issues that need urgent attention in this research are the:-

a. Impact of high arc (fault) resistances during ground fault when high fault currents are injected into the transmission line from various intermediate and remote sources of the protected zones.
b. Effect of in-feed current flow from the various intermediate and remote sources into the protection zone resulting to an impedance error function in the expected output of the distance relay of the double circuit transmission line. This impedance error function caused an additional voltage across the impedance between the relay and the fault point, which needs to be examined.
c. Impact of mutual inductive coupling between conductors due to the presence of the zero sequence current component, I_o in the zero sequence impedance path, which caused a drop in voltage across the parallel or double circuit transmission lines. This drop in voltage produced an error on the apparent impedance measurement of the distance relay.
d. Influence of peak load conditions (loadability effect) when a double or parallel transmission line is overloaded and subsequently trips the line to be out of service because the distance relay recognized the load encroachment as a fault.This

made the load impedance of the tripped line to encroach into the relay's characteristic shape of the next (second) line, which increased the apparent impedance seen by the relay beyond the normal apparent impedance of the second line.

Finally, these focal issues necessitate the need for more research in the area of distance protection scheme in power system so as to bridge the gap in this research study. It is worthy of note that that the improvement in protective relay advancement could be tackled by exploiting measures in both artificial intelligence (AI) and Adaptive protection channelled towards revealing to the various challenges.

REFERENCES

[1]. Abdollahzadeh H., Mozafari B. & Jazaeri M., "A functional auxiliary module for first-zone conventional distance relays of double-circuit lines to eliminate high fault resistance introduced under-reach," Electrical Power and Energy System, 2015, vol. 71, pp. 315–326.

[2]. Abdullah, A. M., & Butler-purry, K. Distance protection zone 3 mis-operation during system wide cascading events : The problem and a survey of solutions. Power Systems Research, 2018, 154, 151–159.

[3]. Abdullah, A. M., & Butler-purry, K., Secure transmission line distance protection during wide area cascading events using artificial intelligence. Electric Power Systems Research, 2019, volume 12, 175-179.

[4]. Achary, K. S. K., & Raja, P., Science Direct Adaptive design of distance relay for series compensated transmission line transmission line Assessing the feasibility of using the Raja demand-outdoor district heat demand forecast National for. Energy Procedia, 2017 117, pp. 527–534.

[5]. Alam, M. N. Adaptive protection coordination scheme using numerical directional over-current relays. IEEE Transactions on Industrial Informatics, 2019, 15(1), 64-73. https://doi.org/10.1109/TII.2018.2834474.

[6]. Alhassan A. B., Zhang X., Shen H., and Xu H. "Power transmission line inspection robots: A review, trends and challenges for future research," International Journal of Electrical Power & Energy Systems, 2020, Vol. 118, doi: 10.1016/j.ijepes.2020.105862.

[7]. Andrichak J.G. & Alexander G.E. "Network Protection & Automation Guide," Alstom Grid, 2017 Stafford, UK.

[8]. Araújo, M. R. & Pereira, C. Distance Protection Algorithm for Long Parallel Transmission Lines with No Common Bus, 2019,. 89(4), 201–212.

[9]. Araújo, M. R. & Pereira, C.. A practical first-zone distance relaying algorithm for long parallel transmission lines. Electric Power Systems Research, 2017 146, 17–24.

[10]. Ashwini, S. M., Nadeem, S., & R, S. S. A Novel Solution for Clearance of High Resistive Faults in High Voltage Transmission Lines, 2018, 4(6), 783–792.

[11]. Azari, M., Ojaghi, M., &Mazlumi, K.. .An Enhanced Adaptive Algorithm to Mitigate Mis-coordination. Journal of Applied Research and Technology, 2015, 13(1), 87–96.

[12]. Badr, M. A., Emtethal, N. H. A., & Abdullah, N. Simulation of Distance Relay for Load Encroachment Alleviation with Agent Based Supervision of Zone-3, . 2017, 3(1), 1–3.

[13]. Bhalja B.R., Maheshwari R.P. and Chothani N.G. "Protection and Switchgear" Oxford Higher Education, 2011, India.

[14]. Biswas, S., & Centeno, V. A Communication based In-feed Correction Method for Distance Protection in Distribution Systems, 2017, 2–6.

[15]. Blackburn Lewis J. &Domin Thomas J., "Protective Relaying (Principles and Applications)," Taylor & Francis Group, Third Edition, New York, 2006.

[16]. Barlase, S.. Smart grids: Advanced technologies and solutions. CRC press, 2017.

[17]. Brahman, A., Novosad, D., Tabrizi, M., Cook, T., Lee, W. J. &Ie, F.. Analytical Approach to Study the Impacts of Mutual Coupling on Transmission Lines Protection Systems, 2019 IEEE Texas Power and Energy Conference (TPEC), 2019, 1, 1–6.

[18]. Chatterjee, B. &Debnath, S. A new protection scheme for transmission lines utilizing positive sequence fault components. Electric Power Systems Research, 2021.

[19]. Chen, Y., Wen, M., Yin, X., Cai, Y., &Zheng, J. Distance protection for transmission lines of Doubly Feed Induction Generator (DFIG) based wind power integration system. International Journal of Electrical Power Energy Systems, 2018, 100, 438-448. doi: https://doi.org/10.1016/j.ijepes.2018.02.041.

[20]. Disyadej T., Promjan J., Poochinapan K., Mouktonglang T., Grzybowski S., &Muneesawang P. , "High voltage power line maintenance & inspection by using smart robotics," in 2019 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), 2019, pp. 1–4, doi: 10.1109/ISGT.2019.8791584.

[21]. Don, A., Africa, M., Journal, I., Africa, A. D. M., Naco, I. K. A., Castillo, J. J. M., Valdes, V. A. R., & Wu, S. R. T. ANN Distance Protection for Transmission Lines, International Journal of Emerging Trends in Engineering Research, 2019.

[22]. Ejike, E. M. Performance Determination and Limitations of the Conventional Impedance Relay Operation for Improving the Protection of Transmission Lines, 2017, 6(08), 369–373.

[23]. El-Arroudi, K., &Joós, G. Performance of interconnection protection based on distance relaying for wind power distributed generation. IEEE Transactions on Power Delivery, 2018, 33(2),620-629. https://doi.org/10.1109/TPWRD.2017.2693292

[24]. Elmore W.A. "Protective Relaying Theory and Applications". Marcel Dekker Incorporated, New York, 2004.

[25]. Esfahani, M. M., & Mohammed, O. Electrical Power and Energy Systems An intelligent protection scheme to deal with extreme fault currents in smart power systems. Electrical Power and Energy Systems, 2020, 115.

[26]. Esmaeilian, A., Popovic, T., &Kezunovic, M. Transmission Line Relay Mis-operation Detection Based on Time-Synchronized Field Data, 2019, 2(3), pp. 34- 41.

[27]. Ezema, C. N., Iloh, J. P. I., & Obi, P. I. Analysis of Distance Protection for EHV Transmission Lines Using Artificial Neural Network, 2017, Volume 2, pp. 1–12.

[28]. Fatemeh, S., Ramezani, N., &Ahmadidounchali, A. Adaptive Zone-2 Distance Protection Scheme for Multi-Terminal Line Connecting Wind Farm, 2016, pp. 1–14.

[29]. Ghorbani, A., Ebrahimi, S. Y., &Ghorbani, M. Active power based distance protection scheme in the presence of series compensators, 2017, https://doi.org/10.1186/s41601-017-0034-4.

[30]. Ghorbani, A., Mehrjerdi, H., & Al-emadi, N. A. Distance differential protection of transmission lines connected to wind farms, Electrical Power and Energy Systems, 2017,89, pp. 11–13.

[31]. Ghorbani, A., Mehrjerdi, H., &Sanaye-Pasand, M. An accurate non-pilot scheme for accelerated trip of distance relay zone-2 faults. IEEE Transactions on Power Delivery, 2021, 36(3), 1370-1379. https://doi.org/10.1109/TPWRD.2020.3007559

[32]. Giral, W., Celedón, H., Galvis, E., &Zona, A. Redesinteligentes en el sistema eléctrico colombiano: revisión de tema. Tecnura,2017, 21(53), 119-137, https://doi.org/10.14483/22487638.12396.

[33]. Gurusinghe D. R. &Rajapakse A. D., "Efficient algorithms for real-time monitoring of transmission line parameters and their performance with practical synchrophasors," IET Generation, Transmission & Distribution, 2017, Vol. 11, no. 5, pp. 1134–1143, doi: 10.1049/iet-gtd.2016.0830.

[34]. Hooshyar, A. &Iravani, R. Microgrid protection. Proceedings of the IEEE, 2017, 105(7), 1332-1353. https://doi.org/10.1109/JPROC.2017.2669342

[35]. Hewitson L.G., Mark Brown, & Ramesh Balakrishnan. "Practical Power Systems Protection", Newnes publisher, First published, 2004.

[36]. Horowitz S. and Phadke. Power System Relaying, 4th edition, WileyPublishers, New York, 2018.

[37]. Hoq, T., Wang, J., & Taylor, N. Review of recent developments in distance protection of series capacitor compensated lines. Electric Power Systems Research, 2021, 106831.

[38]. IEEE Guide. IEEE Guide for Protective Relay Applications to Transmission Lines, IEEE Standard C37.113-1999.

[39]. IEEE Guide.IEEE Guide for Determining Fault Location on AC Transmission and Distribution Lines, IEEE Standard C37.114, 2005.

[40]. Jia, J., Yang, G., Nielsen, A. H., &Rønne-Hansen, P. Impact of vsc control strategies and incorporation of synchronous condensers on distance protection under unbalanced faults. IEEE Transactions on Industrial Electronics ,2019, 66(2), 1108-1118. https://doi.org/10.1109/TIE.2018.2835389

[41]. Jin, X., Gokaraju, R., Wierckx, R., &Nayak, O. (2018). High speed digital distance relaying scheme using FPGA and IEC 61850. IEEE Transactions on Smart Grid, 9(5), 4383-4393. https://doi.org/10.1109/TSG.2017.2655499.

[42]. Jokhio K. A., Sahito A. A., Soomro A. M., and Jiskani S. M., "Transmission line fault detection and identification using artificial neural network," International Journal of Electrical Engineering & Emerging Technology, 2021, Vol. 4, no. 1, pp. 1–7.

[43]. Khalid, H. &Shobole, A. Existing Developments in Adaptive Smart Grid Protection : A Review on Electric Power Systems Research, 2021, 19(1), pp. 23-31.

[44]. Klapper Ulrich, "Measurement of line impedances and mutual coupling of parallel lines," Relay Protection and Substation Automation of Modern EHV Power Systems, Cigre Publication, Moscow – Cheboksary, 2007.

[45]. Kokorin E.L., Dmitriev S.A. &Khalyasmaa A.I., Electrical network reliability assessment with consideration of the secondary circuit effect, 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), 2016, pp. 1-6.

[46]. Li J., Zhang Y., Ma C., and Cheng, C. "Research on multifunctional automatic transmission line automatic robot system," Journal of Physics: Conference Series, 2018, Vol. 1074, doi: 10.1088/1742-6596/1074/1/012010.

[47]. Li, H., Deng, C., Zhang, Z., Liang, Y., & Wang, G. An adaptive fault-component-based current differential protection scheme for distribution networks with inverter-based distributed generators. International Journal of Electrical Power Energy Systems, 2021, 128,106719. https://doi.org/10.1016/j.ijepes.2020.106719.

[48]. Liang, Y., Li, W., Lu, Z., Xu, G., & Wang, C. . A new distance protection scheme based on improved virtual measured voltage. IEEE Transactions on Power Delivery, 2020, 35(2), 774-786. https://doi.org/10.1109/TPWRD.2019.2926295.

[49]. Liang Y., Lu Z., Li W., Zha ,m& Huo Y. A novel fault impedance calculation method for distance protection against fault resistance, IEEE Trans. Power Delievery, 2020, 35 (1), 396–407.

[50]. Liu, S., Jin, X. S., &Gokaraju, R. R. High-speed distance relaying using least error squares method and testing with FPGA. IET Generation, Transmission & Distribution, 2019, 13(16), 3591-3600. https://doi.org/10.1049/iet-gtd.2019.0088.

[51]. Ma J., Xiang X., Li, Z., Deng, J.S. Thorp. Adaptive distance protection scheme with quadrilateral characteristic for extremely high-voltage/ultra-high-voltage transmission line, IET Generation, Transmission and Distribution, 11 (7), 2017, 1624–1633.

[52]. Ma, J., Zhang, W., Liu, J., & Thorp, J. S. Electrical Power and Energy Systems. A novel adaptive distance protection scheme for DFIG wind farm collector lines. International Journal of Electrical Power and Energy Systems, 2018, 94, 234–244.

[53]. Makwana V. H. & Bhalja B. R. Transmission Line Protection using digital technology, Springer publishers, 2016.

[54]. Mallikarjuna, B., Shanmukesh, P., Anmol, D., Jaya, M., & Reddy, B. PMU based adaptive zone settings of distance relays for protection of multi-terminal transmission lines, 2018.

[55]. Menendez O., Auat Cheein F. A., Perez M. and Kouro, S. "Robotics in power systems: enabling a more reliable and safe grid," IEEE Industrial Electronics Magazine, 2017, Vol. 11, no. 2, pp. 22–34, doi: 10.1109/MIE.2017.268

[56]. Meszaros, R. G., K., Barbulescu, C., & Mihalcea, M. Recent trends regarding Distance Protection-A Review, 2017, 8(4), 153–158.

[57]. Mohajeri, A., Seyedi, H., &Sabahi, M. Optimal setting of distance relays quadrilateral characteristic considering the uncertain effective parameters. International Journal of Electrical Power & Energy Systems, , 2015, 73,1051-1059. https://doi.org/10.1016/j.ijepes.2015.06.011.

[58]. Muhayimana O. Distance Protection for Parallel and Double-Circuit High Voltage Lines, MSc Thesis, Brno University of Technology, 2016.

[59]. Nikolaidis, V. C., Tsimtsios, A. M., & Safigianni, A. S. Investigating particularities of in-feed and fault resistance effect on distance relays protecting radial distribution feeders with DG. IEEE Access, 2018, 6, 11301-

11312. https://doi.org/10.1109/ACCESS.2018.2804046.

[60]. Nwohu Ndubuka, M. Performance evaluation of ultra-fast distance protection in shiroro-abuja 330kV transmission line by relay setting re-calibration using Runge-Kutta method. Journal of Electrical/Electronic Engineering Research, 2020, 11(1), pp. 1-5.

[61]. Okundamiya, M. S. Power Electronics for Grid Integration of Wind Power Generation System, 2016, Volume 9(1), pp. 13- 20.

[62]. Onat, N. Trends in Power System Protection Researches : A Review of Fundamental Relays., 2018, 6(4), pp. 1-6.

[63]. Oza B.A., Nair N.C., Mehta R.P. and Makwana V.H. "Power System Protection and Switchgear". Tata Mcgraw Hill, New Delhi, India, 2010.

[64]. Prasad Avagaddi, Belwin Edward J., Ravi K. A review on fault classification methodologies in power transmission systems: Part - I, Journal of Electrical Systems and Information Technology, 2018, 5, 48-60. https://doi.org/10.1016/j.jesit.2017.01.004.

[65]. Regulski, P., Rebizant, W., Kereit, M., & Schneider, S. Adaptive reach of the 3rdzone of a distance relay with synchronized measurements. IEEE Transactions on Power Delivery, 2021, 36(1),135-144. https://doi.org/10.1109/TPWRD.2020.2974587.

[66]. Sarangi, S., Sahu, B. K., & Rout, P. K. Review of distributed generator integrated ac micro-grid protection: issues, strategies, and future trends, International Journal of Energy Research, 2021, 45(10), 14117-14144. https://doi.org/10.1002/er.6689.

[67]. Tsimtsios, A. M., Korres, G. N., & Nikolaidis, V. C. A pilot-based distance protection scheme for meshed distribution systems with distributed generation. International Journal of Electrical Power & Energy Systems, 2019, 105,454-469. https://doi.org/10.1016/j.ijepes.2018.08.022.

[68]. Tsimtsios, A. M., & Nikolaidis, V. C. Setting zero-sequence compensation factor in distance relays protecting distribution systems. IEEE Transactions on Power Delivery, 2018, 33(3), 1236-1246. https://doi.org/10.1109/TPWRD.2017.2762465.

[69]. Tsimtsios, A. M., Safigianni, A. S., & Nikolaidis, V. C. Generalized distance-based protection design for dg integrated mv radial distribution networks - part i: Guidelines. Electric Power Systems Research, 2019a, 176,105949. https://doi.org/10.1016/j.epsr.2019.105949.

[70]. Tsimtsios, A. M., Safigianni, A. S., & Nikolaidis, V. C. Generalized distance-based protection design for dg integrated mv radial distribution networks -part ii: Application to an actual distribution line. Electric Power Systems Research, 2019b, 176, 105950. https://doi.org/10.1016/j.epsr.2019.105950.

[71]. Rajalwal, N. K. Recent trends in integrity protection of power system : A literature review, 2020, 1–43.

[72]. Russell-Mason C. 'The art and science of protective relaying,' Multilin publishers, 2008.

[73]. Savalia, S., Pandya, V., & Kumar, T. V. P. Problem in Distance Protection for Series-Compensated Transmission Line, 2016, 1–5.

[74]. Seghir, S. Fault Resistance Effect on Distance Protection in High Voltage Transmission Fault Resistance Effect on Distance Protection in High Voltage Transmission Lines, 2017.

[75]. Shukla S. K., Koley E., and Ghosh S. "A hybrid wavelet–APSO–ANN-based protection scheme for six-phase transmission line with real-time validation," Neural Computing and Applications, 2019, Vol. 31, no. 10, pp. 5751–5765, doi: 10.1007/s00521-018-3400-x

[76]. Singh, M. Protection coordination in distribution systems with and without distributed energy resources- a review, 2017, pp. 1–17.

[77]. Tziouvaras D., Altuve & Calero, "Protecting Mutually Coupled Transmission Lines: Challenges and Solutions," proceedings of the 67th Annual Conference for Protective Relay Engineers, College Station, Texas, 2014, Volume 5, pp. 36-42.

[78]. Trivedi, N., Pandya, V., & Shah, V. Distance Relay Characteristics suitable for dynamic loading. Journal of Energy and Management, 2016, Volume 1, pp.24–29.

[79]. Uhunmwagho, R., & Okedu, K. E. (2014). Issues and Challenges in the Nigerian Electricity Industry : A Case of Benin Electricity Distribution Company, 2016, 4(9), 35–40.

[80]. Ulla, I., Radwan, M. S., Baharom, M. N. R., Ahmad, H., & Luqman, H. M. Remote in-feed and arc resistance effects on distance

relays settings for 9 bus, WSCC system, 2017.

[81]. Unde, S. V, Dhopte, P. D., Gawande, P. N., & Dambhare, S. S. A New Protection Scheme for Three-Terminal Mutually Coupled Transmission Line, 2018, pp. 14–19.

[82]. Usama, M., Mokhlis, H., Moghavvemi, M., Mansor, N. N., Alotaibi, M. A., Muhammad, M. A., & Bajwa, A. A., A comprehensive review on protection strategies to mitigate the impact of renewable energy sources on interconnected distribution networks. IEEE Access, 2021, 9,3574035765. https://doi.org/10.1109/ACCESS.2021.3061919.

[83]. Uzubi, U., & Ejiogu, E. Artificial Neural Network Technique for Transmission Line Protection on Nigerian Power System, 2017, pp. 52–58

[84]. Vázquez, M. E., Zamora-Méndez, A., Arrieta-Paternina, M. R., Trujillo-Guajardo, L. A., & de la O Serna, J. A., Dynamic phasor-driven digital distance relays protection. Electric Power Systems Research, 2020, 184, 106316. https://doi.org/10.1016/j.epsr.2020.106316.

[85]. Yin, Y., Fu, Y., Zhang, Z., &Zamani, A. Protection of micro-grid interconnection lines using distance relay with residual voltage compensation. IEEE Transactions on Power Delivery, 2021 9369070. https://doi.org/10.1109/TPWRD.2021.3063684.

[86]. Ziegler G. “Numerical Distance Protection: Principles and Applications”. Public Corporate Publishing, SIEMENS, 2008.

[87]. Gopakumar, P.; Mohanta, D.K.; Reddy, M.J.B. Transmission line fault detection and localization methodology using PMU measurements. IET Generation, Transmission & Distribution, 2015, 9, 1033–1042.