International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

High Transient Based Transmission Line Protection using Artificial Neural Network

Shyamal Sanjay Kandalkar[1], Prof. Chetan M. Bobde[2]

[1]*PG Student, G.H.Raisoni University, Amravati*
[2]*Head of Department, G.H.Raisoni Univerrsity, Amravati*

Abstract - *This paper presents a new method based on high transient fault signal and locating faults on three-terminal power lines. For high transient based protection line trap design which tune at normal supply frequency are installed at each end of multi-terminal transmission line. Due to installation of line trap at each end of line protection of transmission line is improved. Also Artificial Neural Network (ANN) is utilized for classifying external and internal fault of transmission line. Transmission line model design in MATLAB simulink and successive results obtain using this technique. ANN successfully classifies the fault upto 90 percent fault cases.*

Key Words: ANN; High transient based protection; Multi-terminal Line

1. INTRODUCTION

Typically, there square measure 3 styles of line configurations used at intervals the business. These line configurations embrace radial configuration that square measure (a) one-terminal, (b) two-terminal, and (c) multi-terminal of that three-terminal is presumably the foremost distinguished multi-terminal types of line. It ought to be noted that "terminals" during this context, refers to supply terminals and not-tapped electrical device terminals or stations. The two-terminal line configuration is that the most dominant kind followed by radial, and therefore the three-terminal lines square measure the exceptions.

Three-terminal and different multi-terminal line construction comes are usually a trade-off of coming up with political economy and protection complexities, and may cause compromises in reliableness. Two-terminal lines with long tap(s) supply remote load from the most line could show several of an equivalent protection and load ability problems as three-terminal lines. These styles of configurations and people with multiple broached electrical device stations (low voltage tie breaker closed) square measure on the far side the scope of this discussion. However, it ought to be noted that a number of an equivalent styles of complexities could also be intimate with these styles of configurations as three-terminal lines

The complexity of protecting these line configurations increases from the relatively simple radial, to the harder two-terminal, and to the still harder three-terminal. Relaying three-terminal lines has been and continues to be a challenge for cover engineers. There are variety of things that influence the choice to configure a cable with three terminals, like economics, constrained time interval, regulatory approvals, right-of-way (RoW) availability, line overloads, and system performance requirements.

2. PROPOSED FAULT CLASSIFICATION SCHEME

2.1. Objective of classification scheme

The dyadic wavelet transform (DWT) is used to decompose the fault signals into different frequency bands and for calibrating the energy of each phase current signal. Then, the signal spectral energy within each frequency band is computed. The Artificial Neural Network (ANN) is used to classify the faults into two categories of internal and external faults according to their frequency spectrum.

2.2. Discrete Wavelet transform for fault classification

It is mathematical tool that decomposes the input signals into different frequency bands. It provides time and frequency domain localization which makes it an appropriate mathematical tool to process non-stationary transient signals [5]. In proposed approach, discrete wavelet transform (DWT) used for decomposed measured signal into different frequency band. The representation of DWT for given signal x(k) with respect to a mother wavelet ψ(k) is can be written as [6]

$$C\,(Scale, position) = \int_{-\infty}^{\infty} f(t)\,\psi\,(Scale, position, t)\,dt \quad (1)$$

Where, ψ belongs to a special wavelets family to compare with *f(t)* is known as “mother wavelet”. Generally, DWT is implemented through multi-resolution analysis (MRA), schematic diagram is shown in figure 1.

The wavelet transform is comparison analysis which determines the amount of similarity of given signal to a shifted and scaled version of predefined basic function. The data window length of wavelet transform can vary through variation of scale factor.

The larger the wavelet energy, the more the information is preserved after decomposition. The definition of total energy and average power for a signal x[n] being expressed as follows in Eqns. (2) & (3).

$$E = \sum_{n=-\infty}^{\infty} x2(n) \quad (2)$$

$$P = \lim_{x\to\infty} \frac{1}{2N} \sum_{n=-N}^{N} xn(n) \quad (3)$$

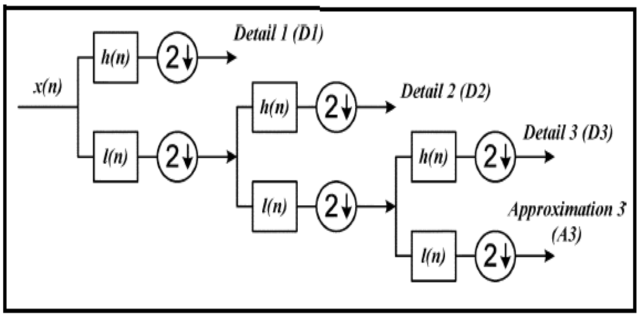

Fig.-1: Wavelet Multi-Resolution Analysis

After successful decomposition process we got energy coefficient of individual signals that transfer to the neural network for classification of internal and external fault.

2.3 Artificial Neural Network for fault classification

A three level back propagation network with proper selection of activation function used as classifier for decimating internal and external fault in protected zone. [7] It is powerful artificial decision tool required training for input data set. Based on training data set it first train with any simulation software (MATLAB). After successful training it classifies the given input data set based on training data set using back propagation algorithm or wait update rule.

In proposed work training data sets generates may be based on following parameter:-

(1) Distance of fault point from relay point.(In km)
(2) Fault type.
(3) Fault resistance.
(4) If possible any parameter related with proposed scheme.

To provide the required training and testing data set, various internal and external faults will be simulated on the transmission system under study by changing fault location, fault type and fault resistance.

The fault signal will be proceed to extract their high frequency spectral energy at different frequency band using wavelet transform. The data sets will be generated and transfer (Low frequency and high frequency signal band) to the two inputs of neural network [7]. Figure 2 depict Fault classification scheme for transmission line. On basis of training data base neural network classify internal and external fault of protected multiterminal transmission line.

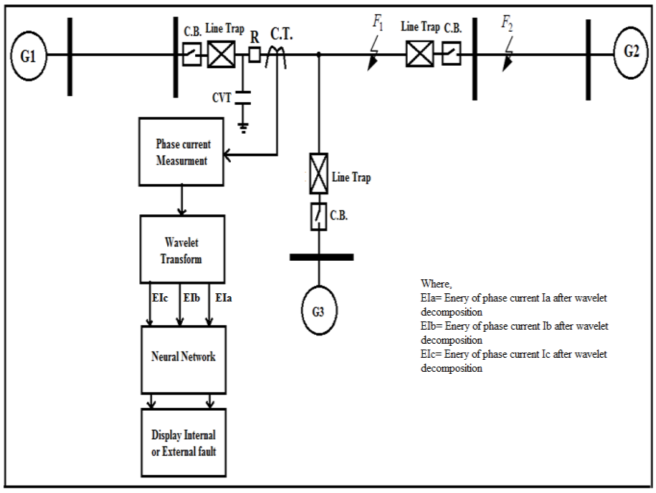

Fig.-2: Fault classification scheme for transmission

2.4 Working of fault classification scheme

This algorithm uses the phase current signals measured at the relay bus. The current signals are first passed through antialiasing filters, and then are sampled at the sampling frequency of 160 kHz. The measured signals are decomposed into different frequency bands using DWT. Meanwhile, using the wavelet transform, a denoising process is performed on the signals to increase the noise immunity of the proposed protection algorithm. Considering the specified sampling frequency, the signals are decomposed up to five stages. The obtained detail coefficients d1, d2, d3, d4, and d5 correspond to the frequency bands of 40–80 kHz, 20–40 kHz, 10–20 kHz, 5–10 kHz and 2.5–5 kHz, respectively. The dyadic wavelet transform is implemented using the filter bank approach which does not impose considerable computation burden. The signal energy at each frequency band is calculated for a 1/4-cycle sliding window.

The calculated signal energy at the defined frequency bands is normalized using the signal energy at the fourth frequency band, and is used as the ANN inputs to discriminate between internal and external faults. The ANN is well capable of constructing appropriate hyperplanes for clustering the input data in a high dimension space.

The processing burden of the proposed algorithm is higher than that of some conventional techniques employed in the impedance-based relays. Nevertheless, considering the advancements in the digital technology and processing speed, this is not a serious problem. Since the proposed algorithm uses a 1/4-cycle sliding data window to calculate the signal spectrum energy, if an appropriate processor is used, the operation time of the proposed algorithm would be about 1/4 cycle of the power system frequency.

3. PROPOSED PROTECTION SCHEME

3.1 Objective of protection scheme

This work presents a new non-communication protection technique for multi-terminal transmission lines using fault-generated high-frequency transients. To minimize influence of the variable power system parameters and conduction on relay performance, appropriately design line traps are installed at the transmission line terminals.

This model improves the performance of distance relay by introducing line traps for providing discrimination between internal fault and external fault. Due to line trap impedance relay can trip during internal fault only. It means that impedance distance relay protect the main transmission line when fault occurs on that line, and not trip the line when external fault occur in outside protected transmission line. Figure- 3 depict block diagram of protection scheme of transmission line.

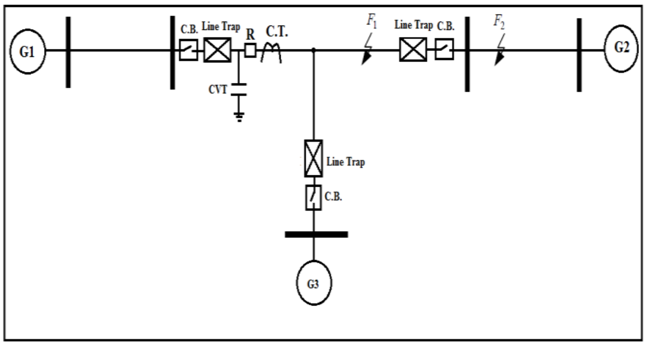

Fig-3: Block diagram of protection scheme of transmission line

3.2 Line Trap

Line traps are connected in series with HV transmission lines at each end to prevent dissipation of the power-line carrier (PLC) signal in the substation or in other transmission lines [8]. The main function of the line trap is to present high impedance at the carrier frequency band while presenting negligible impedance at the power system frequency. A line trap consists of three major components in parallel (i.e., mail coil, tuning device, and surge arrester. The reflection and refraction coeff. of the TL termination points are not affected considerably by variation of the substation parameters. It means that, protective algorithm can well discriminate between internal and external faults.

3.3 Circuit Breaker

The main function of circuit breaker is to isolate the protected transmission line when relay send the trip signal to its in abnormal internal fault condition.

3.3 Circuit Breaker

The main function of circuit breaker is to isolate the protected transmission line when relay send the trip signal to its in abnormal internal fault condition.

3.4 Current transformer(C.T.)

It used to measure the phase current at the relay bus of protected transmission line and transfer that current signal for decomposition process to wavelet transform block [9]. It also supply current signal to current coil of impedance relay for proportional torque development.

3.5 Capacitor voltage transformer (CVT)

It installed at the transmission line ends to measure the phase voltages. CVTs are installed after line trap after the line trap at TL side [9]. CVTs are measure the phase voltage and send it to the voltage coil of relay for proportional torque development.

3.6 Protective Relay (R)

It is sensing element in protection scheme of transmission line and send the trip signal to circuit breaker to isolate the line when abnormal condition occurs[10]. In these protection scheme, we used impedance distance relay which measure the impedance of overall protected multiterminal transmission line with the help of C.T current signal and C.V.T. voltage signals. Protective relay is installed at bus in one end of three-terminal terminal transmission line and is responsible to identify internal fault occurring on three terminal transmission line.

3.7 Working of protection scheme

When the internal fault occurs impedance relay measured the impedance of line, if impedance of line is less than actual set point impedance then relay send the trip signal to the circuit breakers which are installed at each end of multiterminal transmission line. This circuit breakers isolates the multiterminal line from fault. At same time high frequency generated fault signals are reflected towards each terminal of multiterminal transmission line. That high frequency transient surge are not reflected outside i.e. external portion of main protected transmission line with the help of line trap. Hence external line relay not trip and other outside lines are work normally.

When external faults occurs impedance relay measured the impedance of line, if impedance of line is more than actual set point impedance then relay not send trip signals and main protected line works without any disturbance. But impedance measured by outside line relay is less than actual set point impedance then that line get isolate with the help of circuit breakers. At same time fault signal generated outside the main protected line are not refracted toward the main protected multiterminal transmission line bus due to line traps. Hence relay of main protected line not sense any less impedance value and line normally operates.

4. SIMULATION MODEL

4.1 Transmission line model

Generators 1,2,3; Phase to phase rms voltage = 153e3 V; Frequency = 50 Hz; 3 phase short circuit level = 100e6 V; Base voltage = 153e3 V; X/R=7
Transformer 1; Power= 100e6 VA; Primary voltage = 153e3 V; Secondary voltage = 34.5e3 V; Frequency = 50Hz
Transformer 2; Power = 80e6 VA; Primary voltage = 34.5e3 V; Secondary voltage = 400 V; Frequency = 50Hz
Transformer 3; Power = 80e3 VA; Primary voltage = 34.5e3 V; Secondary voltage = 400 V; Frequency = 50 Hz
Transformer 4; Power = 80e3 VA; Primary voltage = 400 V; Secondary voltage= 34.5e3 V; Frequency = 50Hz

Transformer 5; Power = 80e3 VA; Primary voltage = 34.5e3 V; Secondary voltage = 400 V; Frequency = 50Hz
Transformer 6; Power = 100e6 VA; Primary voltage = 153e3 V; Secondary voltage = 34.5e3 V; Frequency = 50Hz
Transformer 7; Power = 100e6 VA; Primary voltage = 153e3 V; Secondary voltage = 34.5e3 V; Frequency = 50Hz
Source impedance1; R1 = 0.381 Ω; L1 = 1e-3 H
Source impedance2; R2 = 3.466 Ω; L2 = 1e-3 H
Source impedance 3; R3 = 0.821 Ω; L3 = 1e-3 H

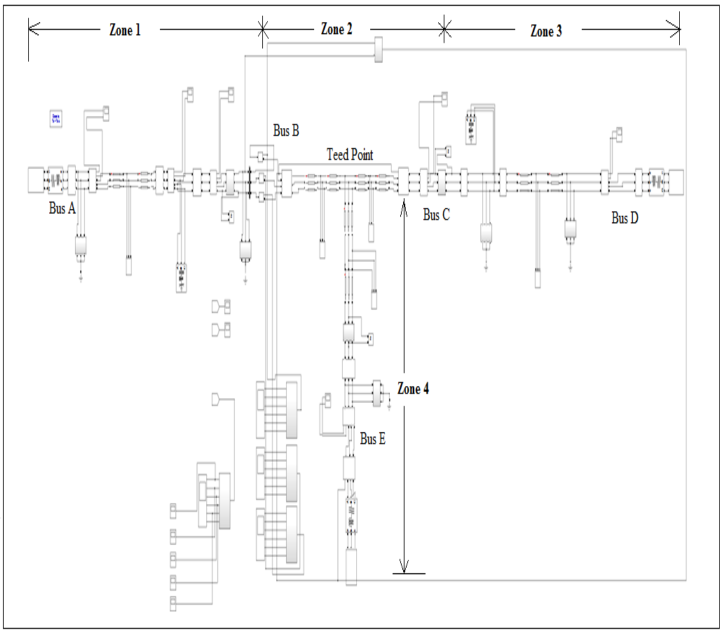

Fig -4: MATLAB Simulation model for Multiterminal transmission line

Figure 4 depict MATLAB Simulation model for Multiterminal transmission line.
Load 1 ; Phase to phase voltage = 400 V; Frequency = 50 Hz; Active power = 0.1 W; Inductive reactive power = 3.5 Positive VAR; Capacitive reactive power = 2.4 Negative VAR
Load 2 Phase to phase voltage= 440; Frequency = 50 Hz; Active power = 0.1 W; Inductive reactive power = 25 +VAR; Capacitive reactive power = 2.4 –VAR

Line Trap 1,2,3; L1 = 2 mH; R1 = 0.5 Ω; C1 = 50 pF; R2 = 50 Ω; C2 = 5 nf, Transmission line model Phase to phase voltage 34.5 KV; Frequency = 50 Hz; Zone1 (AB) = 50Km; Zone2 (BC) = 100Km; Zone3 (CD) = 60Km; Zone4 (EF) = 70 Km.

4.2 Wavelet transform model

The specification of each blocks in Discrete Wavelet Transform subsystem are following way:

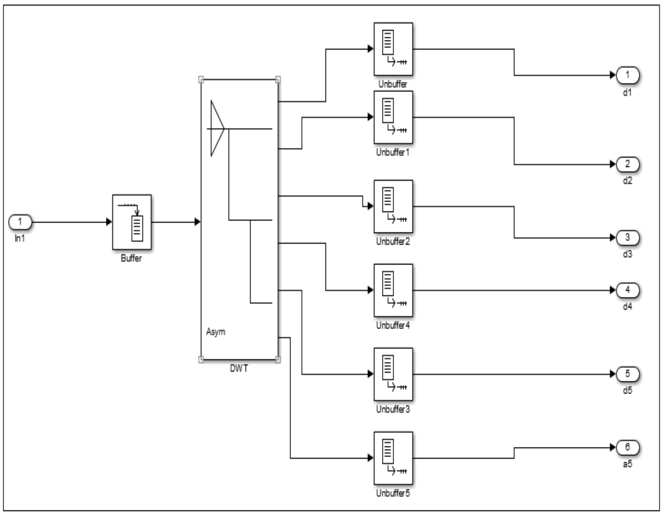

Fig-5: MATLAB simulation model for wavelet multiresolution analysis

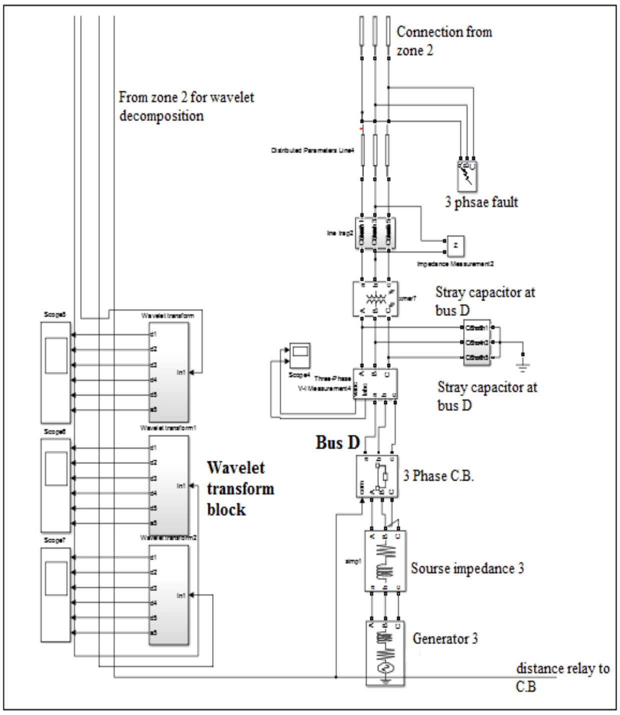

Fig-6: Wavelet transform subsystem in transmission line simulation model

DWT block: Mother wavelet = Daubechies; Wavelet order = 2; Number of levels = 5; tree structure = symmetric; output = multiple ports

Buffer: output buffer size (per channel) = 128; buffer overlap = 0; initial condition = 0, Unbuffer: Initial condition = 0.
Figure- 5 & 6 depict MATLAB simulation model for wavelet multi resolution analysis and Wavelet transform subsystem in transmission line simulation model.

4.3 Line Trap design

According to the IEC 60353 standard, the value of the main coil inductance should not be more than 2 mH [11].

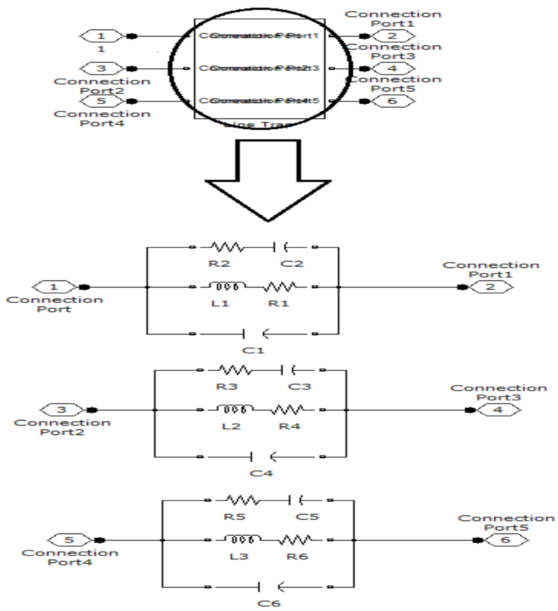

Fig-7: Line trap design in MATLAB simulink

For this value, the voltage drop across the line trap is negligible. For high-frequency studies, the stray capacitance of the main coil should also be modeled. The open, air-insulated design of the main coil results in small inherent capacitances of about 30 to 100 pF, depending on the size of the line trap [12]. Line trap design in MATLAB simulink is shown in figure-7.

5. SIMULATION RESULT

5.1 Results from line trap

The frequency response of the designed line trap is shown in figure 8 considering the frequency band of the fault-induced HF transients, which is mostly in the range of 10–100 kHz, the resonance frequency of the line trap is tuned at 50 kHz.

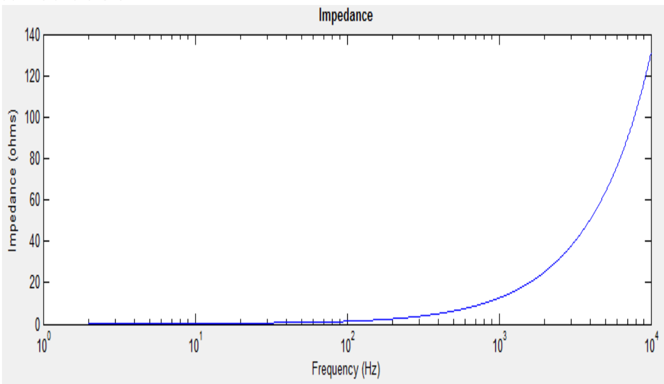

Fig-8: Impedance of line trap at high frequency transients

The main function of the line trap is to present high impedance at the carrier frequency band while presenting negligible impedance at the power system frequency. The high impedance is required to reduce the carrier signal attenuation due to the division among the several transmission lines terminated at the same bus. Figure 8 shows that line trap is present high impedance at the carrier frequency of 100 kHz while presenting negligible impedance at the power supply frequency 50 Hz.

5.2 Results from discrete wavelet transform Decomposition

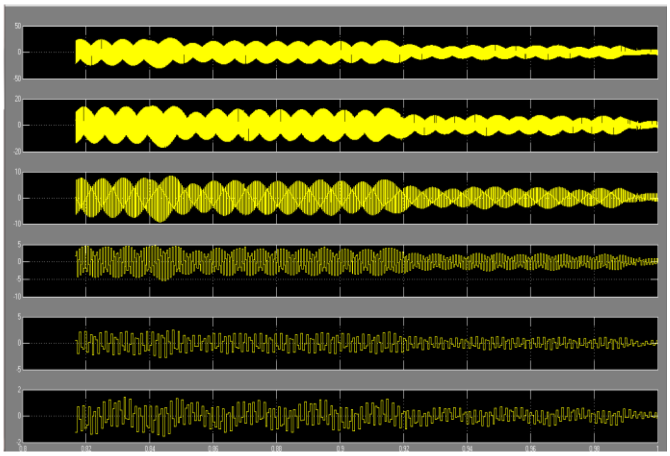

Fig-9: Frequency spectrum of 3 phase current signal for an external fault at 30km from bus B on transmission line AB.

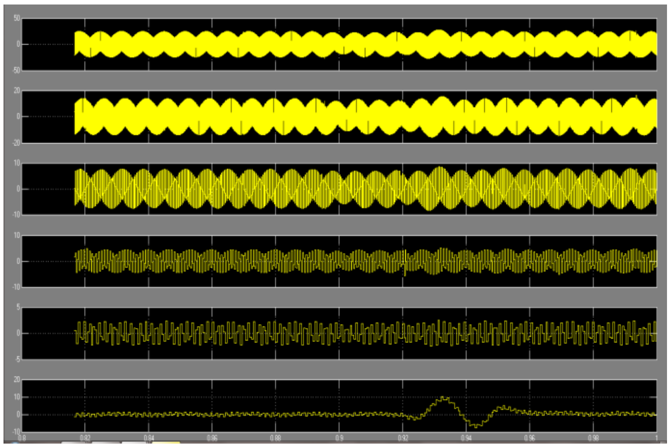

Fig-10: Frequency spectrum of 3phase current signal for an internal fault at 75km from bus B on line transmission line B

Figure- 9 depict the frequency spectrum of combine 3 phase current signal measured at the relay location decomposed by DWT for case of external fault and Figure- 10 shows Frequency spectrum of 3phase current signal for an internal fault at 75km from bus B on line transmission line B.

In that case, an external fault occurs at 30 km from bus B on transmission line AB. As can be seen, for external fault, most of high frequency (HF) components involved in the current signal at frequencies above 20 kHz are not permitted to enter the transmission line under the protection.

5.3 Results from Neural Network

To find out bottlenecks of the HF-based protection technique, initially, the ability of the extracted feature in discrimination between internal and external faults was evaluated through training Artificial Neural Network. The operation time of the proposed technique for all the fault cases is less than 4 msec.

Table-1: Results from Neural Network for different faults condition

Sr.No	Fault type	Location (km)	Fault resistance (Ω)	Ground Resistance (Ω)	ANN Output	ANN error	Target output
1	AG	AB(30)	0.01	0.01	-1	0	-1
2	BG	AB(30)	0.2	0.01	-0.9998	-0.0002	-1
3	CG	AB(30)	0.25	0.01	-1	0	-1
4	ABG	AB(30)	0.3	0.01	-1	0	-1
5	BCG	AB(30)	0.2	0.01	-1	-0	-1
6	ACG	AB(30)	2	0.01	-1	0	-1
7	ABCG	AB(30)	0.3	0.01	-1	0	-1
8	AG	BC(98)	12	2.4	0.9993	0.0003662	1
9	BG	BC(98)	16	3.2	0.9992	0.0001787	1
10	CG	BC(98)	21	3.4	0.9992	8.19E-05	1
11	ABG	BC(98)	24	4.2	0.9996	4.31E-05	1
12	BCG	BC(98)	26	4.4	0.9997	3.15E-05	1
13	ACG	BC(98)	28	4.8	0.9998	2.09E-05	1
14	ABCG	BC(98)	30	0.2	0.9997	3.11E-05	1
15	ABC	BC(98)	0.26	0.8	-1	2	1

As can be seen, the maximum fault classification accuracy is 93.63% for all the faults cases. Table 1 present some of the fault cases for which the design ANN is not able to correctly classify the fault. In this table, the fault location is given from bus B. Most of the misclassified faults are those which occur very close to the remote buses C or E. Indeed, it is difficult to distinguish between faults occurring close to the remote buses on the TL under protection or on the next TLs.

6. CONCLUSION

This work presented a non-communication protection technique for multi terminal transmission lines. The proposed technique uses the fault-generated high–frequency transients to discriminate between the internal and external faults. To minimize the effect of variable power system parameters on the proposed algorithm performance, appropriately designed line traps were installed at the TL ends. The ANN technique was employed to classify the faults according to the fault currents HF components decomposed by the wavelet transform.

The performed simulation studies show that the ANN classifier provides the most accurate result for discrimination between the internal and external faults. Using this algorithm, the reach of the first protected zone can be extended so that only a very small portion at the remote-end side is not covered by the proposed relay. For this small portion, a supplementary algorithm based on the open switching of the remote CB can be used. This is done to maximize the separating margin between the two classes of internal and external faults and provide the required security for the protection scheme. The ANN classifier is able to reliably identify the internal faults up to 96% of the TL length. The proposed algorithm provides high noise immunity and works well even under changes in the power system parameters and conditions due to the installation of appropriately designed line traps at the ends of the protected TL.

REFERENCES

[1] Brahma, Sukumar M. "New fault-location method for a single multiterminal transmission line using synchronized phasor measurements." Power Delivery, IEEE Transactions on 21.3 (2006): 1148-1153.

[2] Izykowski, Jan, et al. "A fault-location method for application with current differential relays of three-terminal lines." Power Delivery, IEEE Transactions on 22.4 (2007): 2099-2107.

[3] Gao, Houlei, and Peter A. Crossley. "A new current differential protection scheme for Teed transmission lines." Power Engineering Society General Meeting, 2006. IEEE. IEEE, 2006.

[4] Daniel, J. S., R. K. Aggarwal, and A. T. Johns. "Three terminal line protection based on a superimposed component impedance relay."Generation, Transmission and Distribution, IEE Proceedings C. Vol. 140. No. 6. IET, 1993.

[5] D. Xingli, G. Yaozhong, and D. Xinzhou, “A wavelet and traveling waves based non-communication high speed transmission line protection,” Autom. Elect. Power Syst., vol. 10, 2001.

[6] V. Pathirana and P. G. McLaren, “A hybrid algorithm for high speed transmission line protection,” IEEE Trans. Power Del., vol. 20, no. 4, pp. 2422–2428, Oct. 2005.

[7] R. K. Aggarwal, A. T. Johns, and Z. Q. Bo, “Non-unit protection technique for EHV transmission systems based on fault generated noise part 2: Signal processing,” Proc. Inst. Elect. Eng., Gen., Transm. Distrib., vol. 141, no. 2, pp. 141–147, Mar. 1994.

[8] T. Nagasawa, M. Abe, N. Otsuzuki, T. Emura, Y. Jikihara, and M. Takeuchi, “Development of a new fault location algorithm for multi-terminal two parallel transmission lines,” IEEE Trans. Power Del., vol. 7, no. 3, pp. 1516–1532, Jul. 1992.

[9] N. Zhang and M. Kezunovic, “Transmission line boundary protection using wavelet transformand neural network,” IEEE Trans. Power Del., vol. 22, no. 2, pp. 859–869, Apr. 2007.

[10] Peyman Jafarian and Majid Sanaye-Pasand, “High-Frequency Transient Based Protection of Multiterminal Transmission Line Using the SVM technique” IEEE Trans. Power Del., Vol.28, No.1, pp.183-196.

[11] Line Traps for Ac power Systems, IEC Standard 60353 Ed. 2.0 b, 1989.

[12] “Line Traps, Product Catalog” Areva T&D Ltd. Co., India. [Online]. Available: http://arevausitr.com.