© 2016 IJSRSET | Volume 2 | Issue 3 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

A Review on Protection Techniques used in HVDC Transmission Line

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ABSTRACT

This paper highlights on the techniques used in the HVDC transmission line protection for the faults occurring at various locations. The different techniques deployed for HVDC protection includes Distance Protection technique, Discrete Fourier Transform technique, Artificial Neural Network technique, Fuzzy logic technique, Wavelet Transform technique, Natural Frequency technique, Independent component technique, Hilbert Huang technique.
Keywords: Discrete Fourier Transform, Artificial Neural Network, Fuzzy logic, Wavelet Transform, Hilbert Huang technique.

I. INTRODUCTION

Today, high voltage direct current (HVDC) is considered superior as compared to high voltage alternating current (HVAC) due to advantages like bulk power transfer capability without intermediate taps, long distances, reduced transmission power losses, Fast operating emergency control systems. Like HVAC, HVDC system is also prone to transmission line losses which leads to instability of the power system and requires high economy to bring back the system to normal operating conditions. There is a need to identify the losses occurred in the system as quickly as possible to prevent the system instability [1]. As compared to overcurrent protection technique, distance relay protection principle is more suitable for fault clearance due to its high speed operation with fast response. The principle of distance protection is to detect the fault occurred at various locations and compares the output with the threshold value which helps to govern the protection zone [2].

The basic techniques for protection of HVDC transmission line uses the voltage and its corresponding rate change for ground fault in dc link since it is prone to fault impedance. With advance techniques in electronics and computerized protection, traveling waves are proved to be more successful in HVDC transmission line. But due to disadvantages like noise affection, inaccuracy in wave head detection, complex and high cost equipments are required to implement with computers, susceptible to external signal interruptions [1]. The numerical protection relays consider Discrete Fourier Transform technique to evaluate the fundamental component through the external signal interruption data comprising fundamental as well as non-fundamental frequency signal component obtained through post fault signals [3].

The global positioning system (GPS), a co-ordinated measurement technique provides real time protection. Phasor Measurements Unit (PMU) is most suitable for measurements co-ordinated with GPS and fault locators through PMUS in many power system applications. This method is mostly preferred over unsynchronized phasors. To achieve dynamically stable system operating conditions like system configuration, fault resistances and generation impedances, a measurement algorithm needs to be developed in optimum way. Considering this as the base reference the intelligent technique like Artificial Neural Network, Wavelet technique and Fuzzy logic are feasible to increase the power system reliability, accuracy, sensitivity, speed of the existing system [4].

II. METHODS AND MATERIAL

Researchers in the past have used different techniques to obtain different output results. The various techniques utilised in the existing system are listed as below:

1. Distance Protection Technique

The technique is adapted based on line parameters nature that are frequency dependent. Hence, for frequency based parameter line model transformation matrix is divided further into two parts: 1) Distribution parameter model (constant parameter model). 2) Frequency based parameter compensation matrix [2].

For end zone faults, fault location determination is obligatory to distinguish between whether the fault is internal or external. Hence, some degree of measurement error is acceptable in distance protection technique since the relay operates only within the particular protection zone and if the fault distance measured is less than the setting distance. The condition for successful operation of the relay is based on the measurement error in the fault location to be less than the difference between the fault location and its setting which is given by:

$$\text{Error (m)} < l_f - l_{set}$$

where, Error (m) is the measurement error, l_f is the fault distance and l_{set} is the setting distance.

This technique requires accuracy in setting of voltage and current calculated value using frequency based parameter model. It helps in reduced measurement errors of distance in cases of faults at far ends.

2. Discrete Fourier Transform Technique

Discrete Fourier Transform algorithm is the most widely used technique for obtaining phasors from the collected or sample data. The equation for the phasor of the signal is given by:

$$X_h = \frac{\sqrt{2}}{N} \sum_{n=0}^{n=N-1} X(n) e^{\frac{-j2\pi hn}{N}}$$

In the above equation, X is the signal phasor, h is the harmonic order, x is the instantaneous value of sinusoidal signal, n is the collected sample data and N is the number of the collected samples from the data. Discrete Fourier Transform is the most efficient technique for recursive implementation in which the computation of new collected data is added and old sample data is subtracted. Discrete Fourier Transform algorithm is most widely used in Phasor Measurement Units as measurement tool in power system [3].

3. Artificial Neural Network Technique

Depending on fault location, the accuracy of electromechanical, static and microprocessor based relay changes along with network configuration. Due to this reason, Artificial Neural Network technique is considered for high speed dynamically system operating conditions. The Artificial Neural Network simplifies any complex input or output to recognise presence of noise pattern and its classification. The disadvantages of conventional relays are overcome by Artificial Neural Network due to the capability to over-reach and under-reach the noise problems. It uses the feature to collect the samples of voltage and current as inputs directly neglecting the phasor and its symmetrical components. To study the fault location, its behaviour and classification, various types of neural networks like multi-layer perceptron, radial basis function, probabilistic neural network are implemented. These networks are designed with algorithms like Kalmar filter, back propagation, orthogonal least square. The advantage of Artificial Neural Network is to extent the distance relay protection zone and thereby providing system security. It is useful to improve the standard function in protection scheme of transmission line for fault direction discrimination, fault identification and its classification, computation of fault distance, series compensated line protection, adaptive distance and reclosing [4,5].

To achieve Artificial Neural Network quick responsive, time varying voltage and current waveform for different network were considered to compare the subsequent output with the previous output recorded through hidden units. In the process of multi-layer network, clustering is necessary to reduce the number of iterations to obtain system security. Artificial Neural Network based distance relay requires huge training sets with increased cost and time consumption. Hence, proper modification of methodology and processing of input data is required

to improve the performance, efficiency and reliability. The present research is towards genetic algorithm for obtaining neural network weights and thereby avoid time consumption and training of Artificial Neural Network [6].

4. Fuzzy Logic Technique

Concept of fuzzy theory was introduced by Zadeh in 1965 dealing with uncertain events. In power system networks, due to varying power system parameters it was necessary to solve these uncertainties. The fuzzy logic technique is useful detect the type of fault in transmission line. Fuzzy logic provides required output explicitly. The fuzzy logic algorithm accuracy depends on assumptions of power flow under pre-fault, line length, resistance of fault, fault distance [4].

Mathematical model of the system is not required for design of fuzzy logic controller. Based on output requirement, qualitative knowledge is needed for design of fuzzy logic controller. Moreover, it is simple to add data or knowledge in terms of system behaviour in the controller model. The major advantage of Fuzzy logic controller is to remain unaffected during variations in system operating conditions and system parameters. The power flow order is modulated through the output of Fuzzy logic controller for DC power modulation. Through large signal modulation obtained from AC system variables, stabilizing control is achieved. The control effect can be improved by reduced short term overloads and increased converter rating for overloads [7].

For wide system variations accuracy is not guaranteed in fuzzy logic protection system. Hence, a more dependable, accurate and secure system needs to be designed for identifying the type of fault under time varying network configurations. These approaches require large training sets and large number of neurons for changes in system frequency which affects the accuracy and protection speed of large networks [8].

5. Wavelet Transform Technique

Wavelet analysis, a new technique in signal processing, is adopted by many researchers now-a-days in power system due to its high capability in frequency as well as time domain analysis [9].

The definition of continuous waveform transform technique for a signal x (t) with respect to base wavelet (t) is given by:

$$CWTT\ (m,n) = \frac{1}{\sqrt{x}} \int_{-\infty}^{\infty} X(t)\ \emptyset \left(\frac{t-n}{m}\right) dt$$

where, m and n are scale and translational factor respectively. For CWTT, t, m, n all are continuous. As compared to Fourier Transform, Wavelet transform requires consideration of base wavelet for various applications. The famous base wavelet considered in power system belongs to Daubechies's wavelet family. In the recent schemes, base wavelet has db5 wavelet for investigating transient signals during fault generation, short duration and fast decaying.

As compared to CWTT, mostly discrete wavelet transform technique (DWTT) is used in many engineering applications like power system networks. The representation of DWTT along with discrete parameters t, m, n is given by equation:

$$DWTT\ (a,b) = \frac{1}{\sqrt{{m_0}^a}} \sum X(t)\, \emptyset \left(\frac{k - b n_0 {m_0}^a}{{m_0}^a}\right)$$

where, the original parameters m and n are transformed to function integers a, b. k is a variable and counts for sample number of input signals. From the DWTT, we can easily adopt the original signal information from different frequency bands and simultaneously information is matched with the relative time period. The original signal can be rebuilt by adding up the wavelet signals at the beginning sample point.

6. Natural Frequency Technique

We can obtain natural frequency method to locate the fault occurrence through the route of DC transmission line. To identify the fault location, travelling wave spectrum is useful to locate the fault. This technique provides relationship between travelling wave spectrum during fault and the fault distance. Based on travelling wave frequency principle, natural frequency of the travelling wave can be located considering transient voltage information after occurrence of the fault. At both ends, using the data, the Pronny algorithm is adopted to obtain the wave natural frequency. Line parameters

cannot be used to calculate the wave speed but can be used to located the fault point precisely. Combined testing model is used to obtain high frequency component of the wave, identify and obtain the precise time parameter and at the end solve the problem of selected wave selection.

7. Independent Component Technique

This technique is highly efficient used recently based on blind separation method. The independent component technique is popularly utilised in feature extraction and speech recognition for small requirement of the target and environment aspects. We can implement fast independent component technique to achieve blind separate the DC voltage and DC current signals that are measured through many channels so that the sequence of data is collected separately along with the key feature of fault record. With the help of independent component technique, after fault we can easily process the current signal of DC transmission line and then decompose the current characteristic signal and finally perceive the time of initial value and the second value measurement point along with polarity relationship to locate the fault. The limits of an independent component technique require source signals to be independent of each other. Mostly Gaussian signal is considered [10].

8. Hilbert Huang Transform Technique

Hilbert Huang Transform is a new technique of signal processing in the frequency analysis of time domain depending on the signal automatically. No need of selection of function and decomposition scale. The Hilbert Huang principle can be applicable to travelling waves to protect the HVDC transmission lines, by observing the waveform, combined with criteria range such as low voltage direct current (LVDC) lines, a new scheme of protection for DC lines is obtained. The decomposition in [10,11] considers envelope fitting problem on decomposition and endpoint which can be improved by designing of new algorithm and cubic spline curve can be implemented to fit extreme continuity to discard endpoint and its effect.

III. CONCLUSION

Hence in HVDC transmission system, long distance and its complex surrounding are the responsible for fault occurrence at distances. Due to these reasons, it becomes necessary to protect the HVDC transmission system and improve the power quality, reliability, accuracy, power flow and stability of the system. Therefore, this paper proves to be more effective in highlighting the various efficient techniques, its advantage, disadvantages and comparison to study the various types of protection techniques and select the particular technique as per the fault location and the parameters required for that technique.

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