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A NOVEL TECHNIQUE FOR THE LOCATION OF FAULT ON A HVDC TRANSMISSION LINE

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ABSTRACT

This paper presents Mathematical Morphological applications to assess the performance of High Voltage Direct Current system. The satisfactory performance of this system is one of the necessary conditions to obtain uninterrupted power supply as it is transmitting bulk power over a long distance. In this paper a 300 kM long HVDC system is simulated for various faults on the DC line and a technique to locate the faults on the DC line is proposed. The simulated results presented in this paper are in good agreement with the published work.

Keywords: HVDC transmission, fault location, mathematical morphology, structuring element.

INTRODUCTION

The industrial growth of a nation demands increased consumption of energy, particularly electrical energy. Generation of electrical energy at increased levels needs to be supported with efficient power transmission system which is capable of transmitting bulk power over long distances with minimum operational losses. Due to rapid technical advancement in power electronics the HVDC transmission has become very efficient means of transferring power in bulk over long distances. Hence, the reliability of HVDC systems has always been of the prime concern in planning and operation of power systems. The long HVDC line cannot be modeled sufficiently with lumped parameters as is done in the conventional AC protection systems. Therefore in the principle and protection criteria of the long HVDC lines, the lines are represented as distributed elements. In AC line faults, the amplitude of the travelling wave generated due to the occurrence of the fault changes with the phase angles. It is more difficult to judge by using travelling waves when the fault occurs near the voltage crossing zero. However, there is no such problem for DC lines; hence traveling wave protection ideally suites for the detection of faults on HVDC line [1]. The main focus of this paper is to apply Mathematical Morphology for analyzing the HVDC system faults.

Digital Signal Processing is distinguished from other areas in computer science by the unique type of data it uses: signals. In most cases, these signals originate as sensory data from the real world like seismic vibrations, visual images and sound waves. DSP is the mathematics, the algorithm, and the technique used to manipulate these signals after they have been converted into a digital form. This includes a wide variety of goals, such as: enhancement of visual images, recognition and generation of speech, compression of data for storage and transmission [2].

Implementation of Mathematical Morphology (MM) requires a set of rudiments defined by a Structuring Element (SE) that is used to process a given signal. A structure element is the smallest part of a structure which when connected to other structure elements makes up a continuum, a boundary or a support of that structure. Selection of SE is to be done appropriately, often by trial and error, since the quality of MM output depends upon it [3].

In this paper a novel technique based on Mathematical Morphology is used to analyze a signal generated from the HVDC transmission system during various operating conditions.

SIMULATION MODEL

A standard 12 pulse HVDC system under the MATLAB environment is used for the analysis and simulation (Figure-1). The simulation model is a 1000 MW (500Kv, 2KAmp) DC line is proposed to transmit power over a 300 km transmitter line from a 500 Kv, 5000MVA, 60Hz network to a 345Kv, 10,000MVA and 60Hz Network. HVDC system is designed to acquire data at a sampling frequency of 80 kHz. The HVDC system model has been simulated for DC line fault. The DC line data is recorded at the rectifier side and is used for the analysis. The data recorded from the rectifier side has been used to calculate the voltage magnitude of the Reverse Voltage Travelling Wave (RVTW). The RVTW has been used for the analysis and location of faults on the system. The calculated RVTW of the transmission line has been analyzed using Signal Processing method.

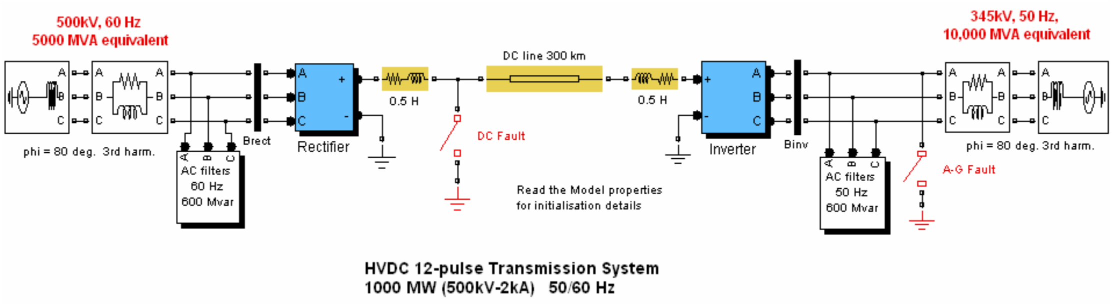

Figure-1. HVDC system.

MATHEMATICAL MORPHOLOGY

Mathematical Morphology is concerned with the filtering and analysis of a given signal by using structuring elements. These structuring elements are special type spatial frequency filters or templates that carry geometric shape information.

Dilation and erosion are two basic operations in MM. Based on these two; several other compound operators such as opening, closing, hit or miss, top-hat transform are defined. Signals in power systems are usually one-dimensional. The most commonly used operations for such signals are dilation, erosion, opening and closing.

Opening generally smoothes the sharp edges in a contour, whereas closing fills narrow valleys and gaps in a contour. Based on these basic operators, various other composite filters and operators are defined. Morphological median filter (MMF), open-closing maximal and close-opening minimal (OCCO), generalized multi-resolution morphological gradient (GMMG), multi resolution morphological gradient (MMG), series MMG, close-opening-open-closing morphological gradient (COOCG) are some examples.

REVERSE VOLTAGE TRAVELLING WAVE

The HVDC line is a distributed parameter line and hence it has the ability to support travelling waves of voltage and current. A circuit with distributed parameters has a finite velocity of electro magnetic field propagations. In such a circuit the change in voltage and current owing to switching lightening or short circuit, do not occur simultaneously in all parts of the circuit but spreads over in the form of travelling wave or surge. The transmission line is represented as LC combinations. The voltage at successive sections builds up gradually. The current wave associated with the voltage wave charges the capacitance travelling from one end to the other end. The current waveform sets up the magnetic field in the surrounding space. At the junctions, these travelling waves undergo reflections and refractions [4].

The reverse voltage travelling wave is calculated by;

$$V_r = \frac{V_{dc} - Z_c I_{dc}}{2}$$

Where V_{dc} and I_{dc} are the voltage and current of the DC line, respectively and Zc is the surge impedance of the HVDC line.

RESULTS AND DISCUSSIONS

The Reverse Voltage Travelling Wave (RVTW) calculated from the voltage and current signals measured at the rectifier end is used to analyze and identify the faults on the HVDC Transmission Line. This paper analyses the given signal and produces dilating and eroding objects. By doing opening and closing operations on the dilated and eroding objects and by analyzing the closing object the technique for the location of the faults has been proposed. Figure-2(a,b,c,d,e,f) shows the Reverse Voltage Travelling Wave during various operating conditions of the HVDC system.

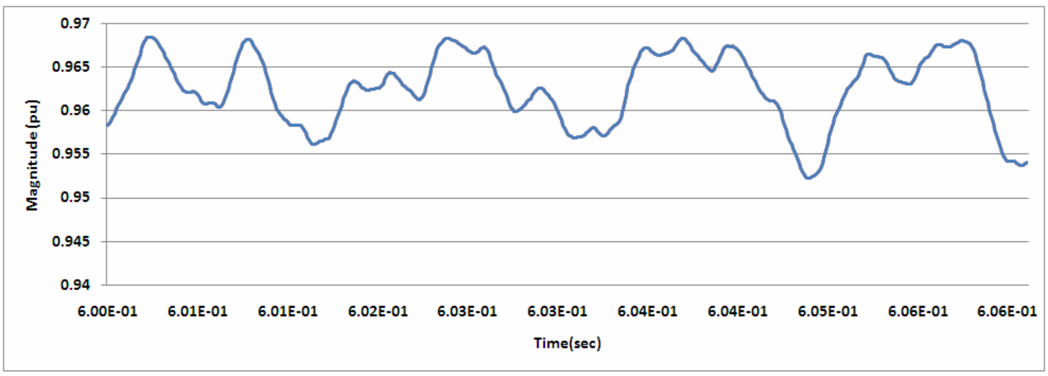

Figure-2(a). Reverse voltage travelling wave during normal operation.

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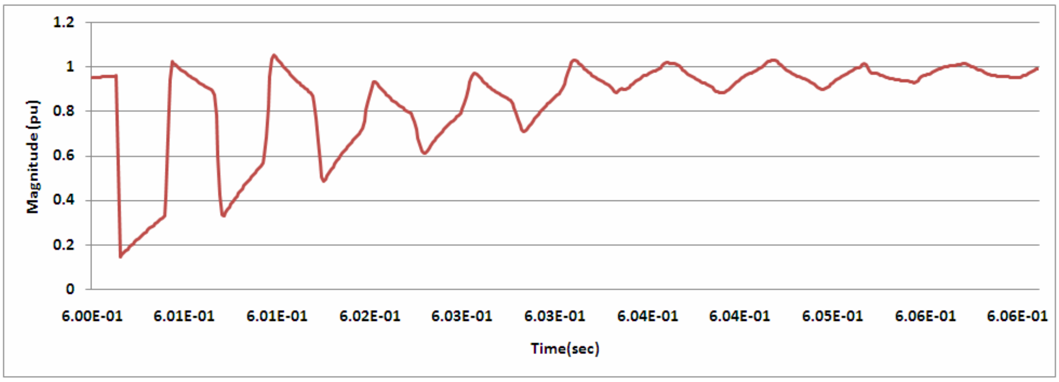

Figure-2(b). Reverse voltage travelling wave during DC line fault at 50kM from the rectifier end.

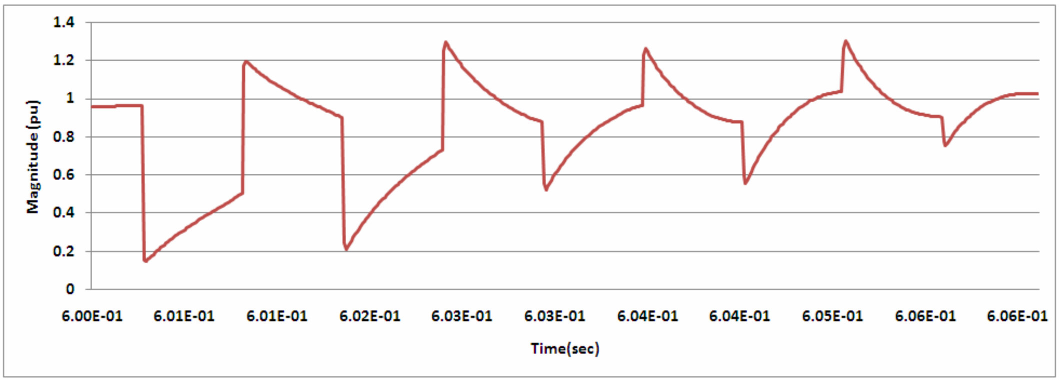

Figure-2(c). Reverse voltage travelling wave during DC line fault at 100kM from the rectifier end.

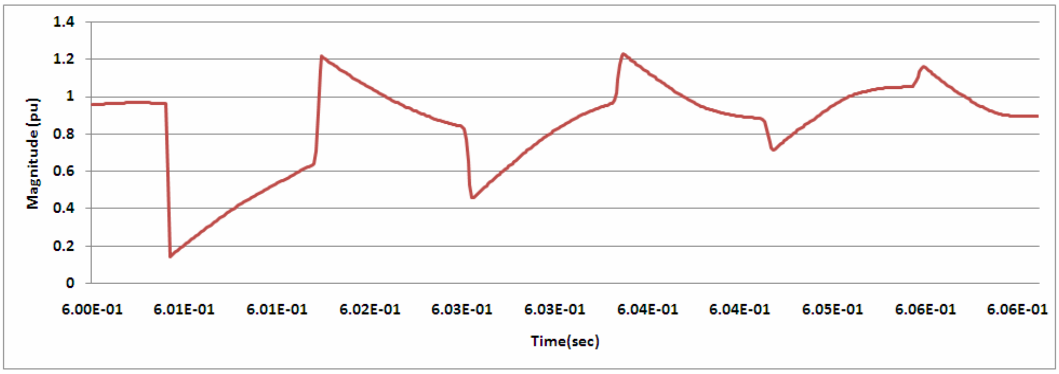

Figure-2(d). Reverse voltage travelling wave during DC line fault at 150kM from the rectifier end.

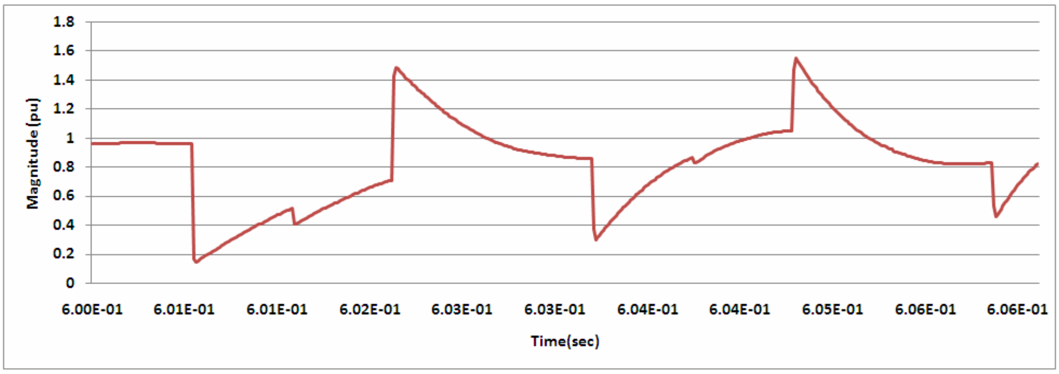

Figure-2(e). Reverse voltage travelling wave during DC line fault at 200kM from the rectifier end.

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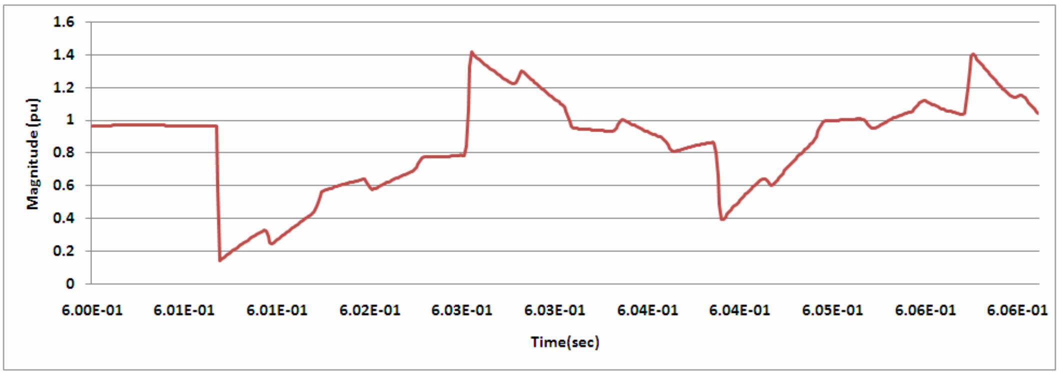

Figure-2(f). Reverse voltage travelling wave during DC line fault at 250kM from the rectifier end.

The RVTW has been analyzed by using the MM Technique. These results are presented in Figure-3(a,b,c,d,e,f).

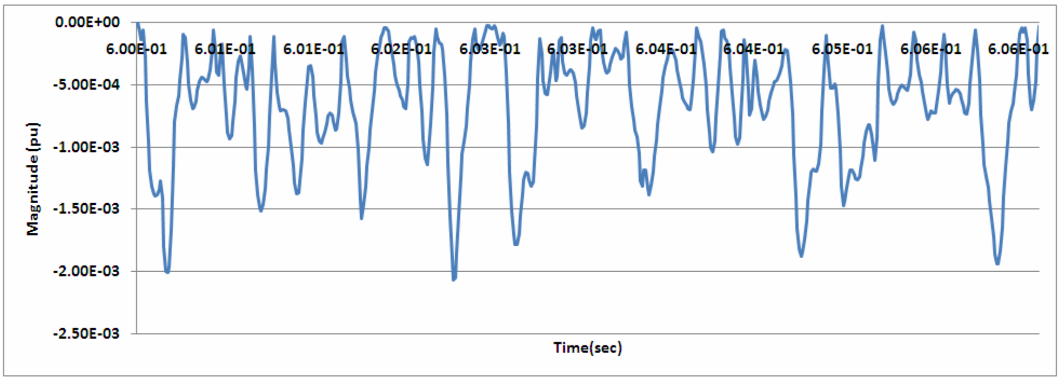

Figure-3(a). Closing operation during normal operating condition of the HVDC system.

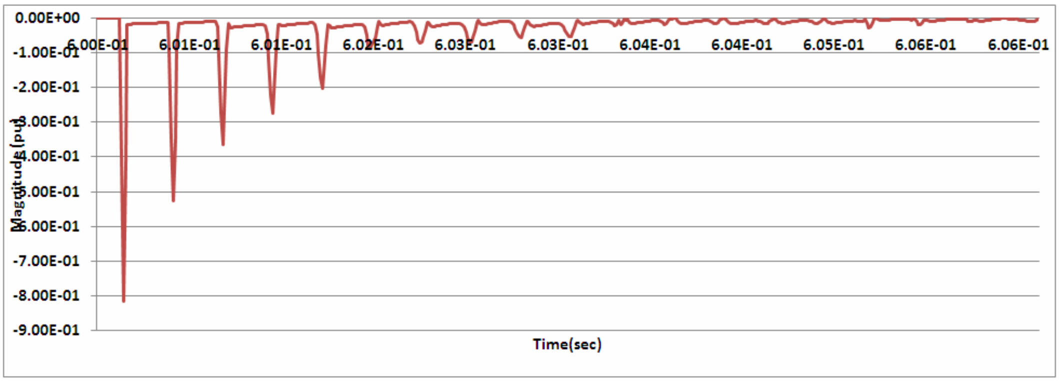

Figure-3(b). Closing operation of the RVTW during DC line fault at 50kM from the rectifier end.

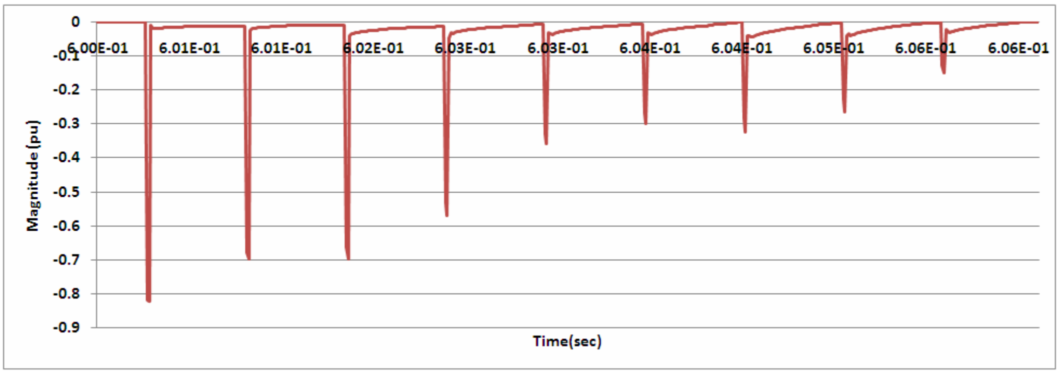

Figure-3(c). Closing operation of the RVTW during DC line fault at 100kM from the rectifier end.

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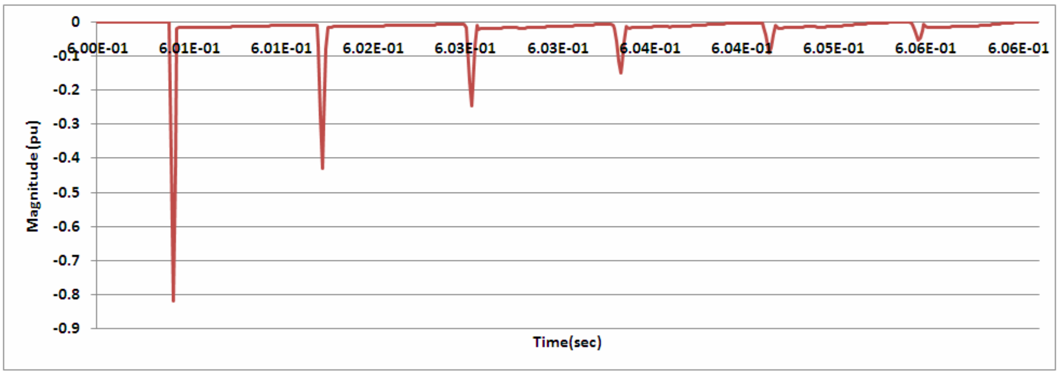

Figure-3(d). Closing operation of the RVTW during DC line fault at 150kM from the rectifier end.

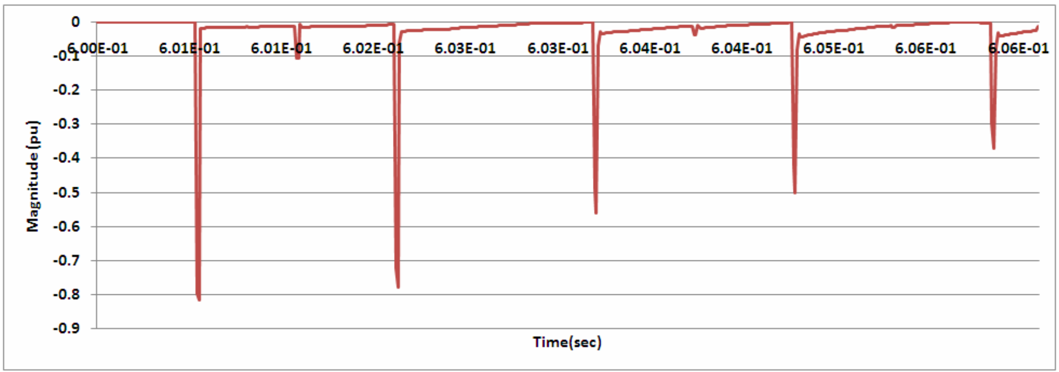

Figure-3(e). Closing operation of the RVTW during DC line fault at 200kM from the rectifier end.

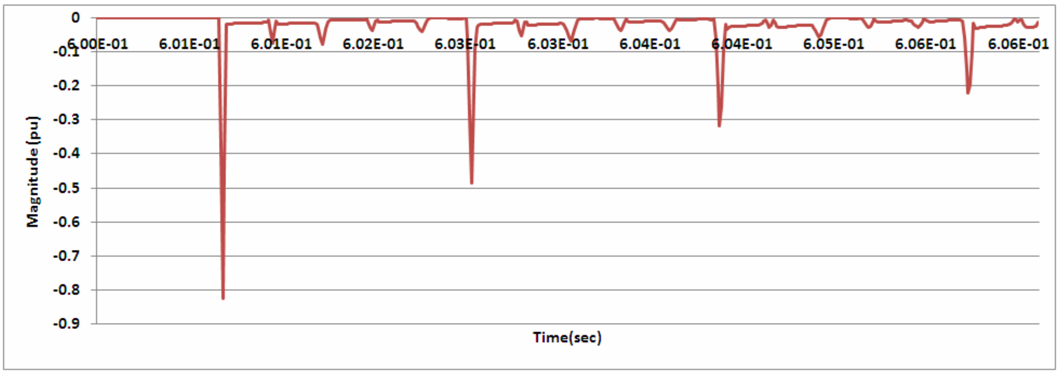

Figure-3(f). Closing operation of the RVTW during DC line fault at 250kM from the rectifier end.

From the closing operation the following observations were made:

- The magnitude of the closing object is very much low during normal operating condition.
- The magnitude of the closing objects during DC line fault is high when compared to the normal operating condition.
- The location of the fault can be measured by measuring the time between two peak values of the absolute closing object.

Table-1 indicates the time intervals between two peaks on the closing objects of the given RVTW and the location of the fault calculated.

The location of the fault depends on the following parameters.

a) Velocity of the wave
b) Time duration taken to travel over the Transmission Line

Location of faults on DC transmission line

When a fault occurs, the fault generated travelling wave propagates along the transmission line [5]. The wave front starts at the measuring location at the time $t = t_1$, again the wave front reaches back the observing location at time $t = t_2$, then the location of the fault can be measured by:

$$D = \frac{v \times \Delta t}{2}$$

Where

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D = Distance from the fault location to the measuring location
v = Velocity of the travelling wave in Km/sec
t = Time delay in sec. (where $\Delta t = t_2 - t_1$)

Table-1. Fault location using morphology technique.

S. No.	Fault location in kM	t1 (sec)	t2 (sec)	Δt (sec)	Fault location using MM in kM
1	50	0.000188	0.000525	0.000338	50.625
2	100	0.00035	0.001025	0.000675	101.25
3	150	0.000525	0.001538	0.001013	151.875
4	200	0.000688	0.00205	0.001363	204.375
5	250	0.000863	0.00255	0.001688	253.125

Table-1 indicates the location of faults on the HVDC transmission line Vs the actual location of the fault by using the morphology technique.

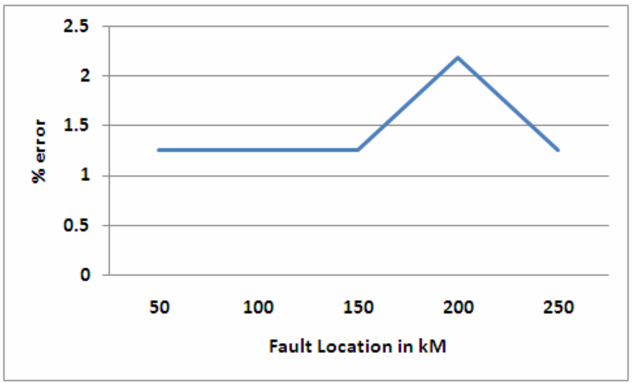

Figure-4. % error vs. location of fault.

From Table-1 and Figure-4 it is clear that the accuracy of the fault location is much higher and is good for the faults nearer the measuring location. The accuracy of the fault location is identified as 98.56% with an average error of 1.44%.

CONCLUSIONS

In this paper a novel signal processing technique has been proposed and applied for the analysis of various operating conditions. DC line faults at various distances (50, 100, 150, 200, 250kM) from the rectifier end were analyzed and presented in this paper using MM. The technique for the classification of fault is proposed. Fault location technique based on closing operation is presented. It is observed that 98.56% accuracy is identified in the location of fault.

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