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HVDC Transmission Line Protection Based on Transient Power

Sherin Tom[a]*, Jaimol Thomas[b]

[a]*PG Student, Saintgits College of Engineering,Kottayam, Kerala, India*
[b]*Professor, EEE department, Saintgits College of Engineering, Kottayam, Kerala, India*

Abstract

This paper presents a new protection method for High Voltage Direct Current (HVDC) system based on transient power. Behavior of the HVDC system during fault is studied. Variation of transient power and the relation between various parameters of the line are analyzed during each fault. Based on that the protection principle is developed. Transient power is obtained by measuring the voltage and current at the two terminals of the line. Identification of internal and external faults as well as location of DC lone fault can be done correctly and quickly from transient power. The test system is modeled using MATLAB - SIMULINK based on first CIGRE HVDC benchmark system.

*Keywords:*High voltage direct current transmission, transients, fault location and identification

1. Introduction

With the ever increasing demand for electrical power, there is a need for increased power transmission capacity over long distances. Implementing the increased power generation into an existing power system is a challenge for the AC networks. To overcome this challenge, increased interconnection of load centers with the use of high voltage direct current (HVDC) has been proposed as an efficient and economical solution.

* Sherin Tom.
*E-mail address:*sherintom09@gmail.com

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The HVDC transmission system has obvious advantages in long-distance bulk power transmission and interconnection between bulk HVAC systems [1]. Most HVDC lines are used for transmission of power over long distance, inevitably passing through complex terrain and operating under harsh weather conditions. Therefore, faults frequently occur on the line which is a major cause of HVDC outages.

Presently, traveling-wave-based protection and voltage derivative protection are usually used as the main protection for HVDC transmission lines, while backup line protections are composed of dc under-voltage protection and current differential protection [2]–[4]. However, traveling-wave-based protection and voltage derivative protection are sensitive to fault transition impedance. Undervoltage protection is low in reliability and current differential protection operates with time delay up to hundreds of milliseconds [4]. Unnecessary HVDC system outages caused by the shortcomings of the present protections in operation have been reported in [3].Given this background, novel HVDC transmission-line protection, which has better performance than the presently used protection, is developed in this paper.

The new method is based on the transient power data. Modeling of the system is done in MATLAB based on first CIGRE HVDC Benchmark system.

2. Principle of Protection

In Fig.1 the main structural diagram of the typical HVDC transmission system is shown [5], [6]. Protection devices are installed at points X at the rectifier side and Y at the inverter side. I_X and I_Y are dc currents, V_X and V_Y are dc voltages at X and Y. The positive directions of currents and voltages are defined in the diagram.

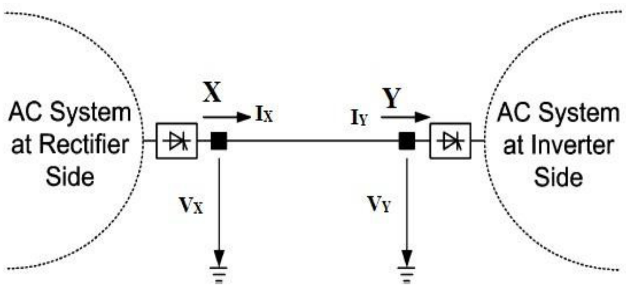

Fig.1. Typical structural diagram of HVDC transmission line

The power at the two points is given by,

$$\left.\begin{aligned} P_X &= V_X I_X \\ P_Y &= V_Y I_Y \end{aligned}\right\} \quad (1)$$

The increment of the transient power during any disturbance is given by,

$$\left.\begin{aligned} \Delta P_X &= \Delta V_X \Delta I_X \\ \Delta P_Y &= \Delta V_Y \Delta I_Y \end{aligned}\right\} \quad (2)$$

Thus, the increment of transient power in the dc line is

$\Delta P = \Delta P_X - \Delta P_Y (3)$

At steady state condition, $\Delta P_X = \Delta P_Y = 0$. Then, $\Delta P = 0$. When a fault occurs difference in transient power will no longer be zero. The value of ΔP will depend on the type of the fault.