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Evaluation of Capacitive Current Compensation Strategies to Current Differential Protection for Long Distance Transmission Lines

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***Abstract*—** In UHV and EHV, distributive capacitive current to current differential protection has serious problem. Nowadays, to deal with the problem of distributed capacitive current a stimulating modern technology is being used in current differential protection with high operating threshold. Many schemes have been used into current differential protection for capacitive current compensation, which was based on shunt reactor, phasor compensation algorithm, Bergeron method. Those techniques were also reducing operating speed and sensitivity of current differential protection. To solve the problem of distributed capacitive current of the line, novel principle of current differential protection is described in this article. Current calculated from set point to both the ends give rise to a differential criterion. Differential protection is launched under the phenomenon of low sampling frequency to improve the expediency of the criterion. The calculation of set point distributed current is achieved at low sampling frequency by adding an interpolation point at each sampling interval. The point is set in the middle of the line and the calculation for magnitude of the current is done with half data window absolute value integrals, for improved the operating speed of the current differential protection.

***Keywords*—** capacitive current, current differential protection, UHV and EHV, low sampling frequency, distributed line model

I. INTRODUCTION

Nowadays, voltage level of the transmission lines is normally 230kV-800kV for extra high voltage (EHV) and higher than 800kV for ultra high voltage (UHV). The superiority of the line will be changed if any type of in-sidle error occurs in the transmission line. In such type of internal fault, protection needed to minimize the error as soon as possible with high sensitivity and reliability of the device. High sensitivity senses the fault very swiftly and high reliability cuts the line very shortly.

Current differential protection is the most important protections of the line which trips immediately under fault circumstances, due to high sensitivity, simplicity and first-rate reliability of the fault selection [1-2]. However, selectivity and reliability of the current differential protection has been mostly affected by the distributive capacitive current of the long-distance transmission lines [3]. The distributive capacitive current increases when the voltage level rises and the length of the transmission line increases [4]. In short transmission lines, differential relay based on instantaneous value is used to solve the problem of distributive capacitive current [5]. However, modern technologies use higher operating threshold value of current differential protection for the solution of distributive capacitive current of the long-distance transmission lines. Sensitivity and dependability of current differential protection is lowered by higher operating threshold valve. It has been proved that sensitivity and dependability of differential current protection needs low sampling frequency and small value of operating threshold.

II. OVERVIEW OF NEWLY USING SCHEMES FOR DISTRIBUTIVE CAPACITIVE CURRENT COMPENSATION

A. Use of Shunt Reactor

The effect of self excitation and line frequency over voltage on UHV and EHV long-distance transmission lines have been eliminated by using shunt reactor, and also compensate the capacitive current under compensation mode. Shunt reactor is compelling to compensate the steady state capacitive current and power frequency but invalid to compensate the transient distributive capacitive current. In addition, external fault or normal fault occurs in the transmission lines, current differential protection might be trip even using shunt reactor. So it's concluded that shunt reactor is not properly suitable to compensate the capacitive current for current differential protection on UHV and EHV long-distance transmission lines according to report reference [6].

B. Phasor Based Compensation Algorithm

According to the report referenced as [7], transient capacitive current is extremely massive as compared to steady state capacitive current when a fault occurs in the lines, particularly in case of fault or without fault conditions of the line. Phasor-based compensation algorithm for current differential protection cannot compensate the transient

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capacitive current. In addition, phasor-based compensation algorithm does not meet the requirement of the relay protection in the field of modern electric power system [8]. Even the half-cycle or full-cycle Fourier transformation that is used in this algorithm requires the huge long data window as well as extensive holdup.

C. Bergeron Method Base Compensation Algorithm

Theoretically, distributed parameter line model or Bergeron line model for current differential protection has solved the problems of steady state capacitive current and transient capacitive current according to the report referenced as [9-10]. Practical terms and circumstances, shunt reactor current of the long-distance transmission line cannot be eliminated by using Bergeron line model, and also needs high sampling frequency. From the above analysis we get the conclusion that high sampling frequency and heavy calculation decreases the sensitivity and reliability of current differential protection [11].

D. Capacitive Current Compensation uses Time-domain Algorithm

Sample data that is based on PI equivalent circuits of the transmission lines is used for compensation. The time-domain algorithm effectively and efficiently compensates the transient and the steady state capacitive current of the transmission line. Time-domain algorithm works so effectively that it will never raise the transmission traffic, the burden of calculations and rate of sampling. Algorithm leads to the speedy tripping, good sensitivity and selectivity, it is appropriate for the protection scheme with 5ms long-data window. However, PI equivalent circuits greatly affected by the transient capacitive current of the line [12].

E. Capacitive Current Compensation Based on Integrated Impedance

Based on integrated impedance, propose transmission line pilot protection is elaborated in [13] in case if relay protection is concerned. The dilemma of capacitive current can be overcome and the analysis of network topology of transmission lines can be done by the protections. Though PI parameter model is applied in this case and transient component affects the extraction of the primary component in frequency, therefore, the principle delays the operation or reduces the sensitivity of the system.

F. Sampled Value Based Current Differential Protection

Sampled value differential protection has solved the problem of capacitive current of the lines and operated quickly, whenever fault occurs on the long-distance transmission lines. However, using sampled value for differential protection is greatly affected by harmonics components. Practically, the sensitivity and reliability of the current differential protection is decreased by harmonics components [14-15].

G. Travelling-Wave Oriented Current Differential Protection

Theoretically, current differential protection based on traveling-wave is not affected by the distributive capacitive current of the transmission lines and also has fast speed operation. Practically, travelling wave is a major setback as travelling wave signal is much receptive to interruption for current differential protection while working on UHV and EHV transmission lines according to the report referenced as [16]. From the above analysis it is concluded that consistency of the current differential protection also has one of the big problem.

H. Novel Principle Based on Distributed Model using Low Sampling Frequency

A novel principle of current differential protection which is based on distributed parameter line model using time-domain algorithm with the help of low sampling frequency has solved the problem of steady state capacitive current and transient capacitive current for long-distance transmission lines as verified by [17-18]. The explanation of novel principle for current differential protection to long-distance transmission lines is given below.

Current differential principle is Kirchhoff's current law (KCL) oriented. In distributed transmission line model, KCL doesn't executes, therefore, in order to prove the presence of KCL in long-distance transmission line distributed parameter model oriented, a point Q is set at middle of the line as shown in Fig. 1. In Fig.1 E_m and E_n are two voltage sources of m and n terminal of the line, l is the total length of transmission line, x is the distance from m terminal to midpoint Q and $l-x$ is the distance from n terminal to midpoint Q . u_m , u_n are two voltages of terminal m and n and i_m , i_n are two currents of m and n terminal of the transmission line.

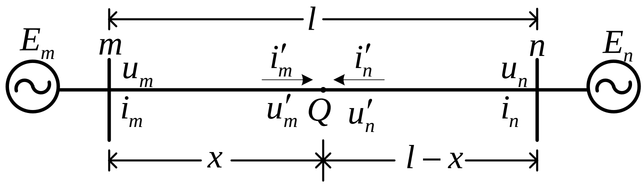

Fig. 1 Model of distributed transmission system

Actually, conductance can be neglected from the transmission line due to the lower value. After that resistance, inductance and capacitance parameter are essential for transmission line. The value of per unit length of the resistance, inductance and capacitance are used in novel principle for current differential protection respectively. Time-domain algorithm which is given below is used to calculate the value of i'_m, i'_n, u'_m and u'_n along the line.

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$$
\begin{aligned}
i'_m(x,t) = {} & \frac{1}{2Z}\left(\frac{Z + R.x/4}{Z}\right)[u_m(t + x/v) - i_m(t + x/v)\cdot(Z + R.x/4)] - \\
& \frac{1}{2Z}\left(\frac{Z - R.x/4}{Z}\right)[u_m(t - x/v) + i_m(t - x/v)\cdot(Z - R.x/4)] - \\
& \frac{1}{2Z}\cdot\frac{R.x}{2Z}[u_m(t) - i_m(t)\cdot(R.x/4)]
\end{aligned}
\tag{1}
$$

$$
\begin{aligned}
i'_n(l-x,t) = {} & \frac{1}{2Z}\left(\frac{Z + R.(l-x)/4}{Z}\right)[u_n(t + (l-x)/v) - i_n(t + (l-x)/v)\cdot(Z + R.(l-x)/4)] - \\
& \frac{1}{2Z}\left(\frac{Z - R.(l-x)/4}{Z}\right)[u_n(t - (l-x)/v) + i_n(t - (l-x)/v)\cdot(Z - R.(l-x)/4)] - \\
& \frac{1}{2Z}\cdot\frac{R.(l-x)}{2Z}[u_n(t) - i_n(t)\cdot(R.(l-x)/4)]
\end{aligned}
\tag{2}
$$

i'_m and i'_n currents is taken by using equations (1) and (2). For getting enough points in transmission line, high sampling frequency must be used in time-domain algorithm. For solving this problem, data interpolation has been used with low sampling frequency in time-domain algorithm based on distributed parameter line model. When differential criterion is applied on current differential protection as we can clearly see in [17-18], novel principle works very well as compared to traditional principle. Whenever fault occurs in the long-distance transmission line, novel principle has approximately zero capacitive current after compensation but traditional principle might be trip due to large distributive capacitive current in it. So it's concluded that novel principle described in this article is enduring the distributed capacitive current of the line, as being compared with the traditional differential current protection. UHV and EHV when transmitted on long distance have been applied on with this methods for getting the appropriate preferred results. Moreover, novel principle has fast operation, high sensitive and dependability.

III. CONCLUSION

From the above analysis of different compensation plans for current differential protection, the final conclusion is mentioned below:

(1) Techniques from A to G have been influenced by capacitive current for current differential protection of the long-distance transmission line, sensitivity and reliability will be decreased.

(2) Novel principle which described in this paper is not influenced by the distributed capacitive current, and also fully works on steady state and transient capacitive current [17-18].

(3) By adding interpolation at each sampling point with low sampling frequency has been achieved, which is not defect of time-domain algorithm.

(4) In novel principle, the compassion and dependability of current differential protection is higher because the value of differential criterion is small.

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