Adaptability Analysis of Sampled Value Differential Protection in Bus with Double-Fed Wind Farm Entrance Line

Jiehui Song*, Bingyuan Yang and Junjie Wu

School of Electric Power, Inner Mongolia University of Technology, Hohhot 010080, China

*Corresponding author e-mail: 2642750300@qq.com

Abstract. When there is a fault located in a bus with the incoming line of doubly-fed wind field, the short-circuit current will contain the weak feed, frequency offset and other fault characteristics of the double-fed wind farm. This will restrict the rapidity of differential protection of the bus sampled value to a certain extent. In this paper, a sampled value differential protection model in bus with doubly fed wind farm incoming lines is built based on RTDS simulation platform. Through simulation, it is proved that the adaptability of the sampled value differential protection in the background is poor.

1. Introduction

Sampled value differential protection has the characteristics of simple algorithm, fast calculation speed, easy to consider CT saturation and so on. It is widely used in the digital bus protection device. Some classical principles of the bus sampled value differential can refer to the literature [1-4]. CT saturation may affect bus differential protection [5]. The amount of voltage introduced in the current of busbar differential protection can theoretically eliminate synchronization problem due to sampled time [6].

As large-scale new energy sources such as wind power are connected to power systems, this poses serious challenges for relay protection based on conventional thermal power setting. Taking the doubly fed wind farm as an example, the influence of wind field incoming line on busbar differential protection is studied in this paper. The type of wind turbine, its operating status, the adopted control strategy, the type of fault and the weak power characteristics of the wind farm will affect the wind power access to the fault current of the power system [7, 8]. Due to the influence of the control of the excitation converter, the DFIG stator and rotor short-circuit currents may contain abundant low-frequency harmonic components [9]. In addition, it was found that the incoming line of the wind field will cause the delay of the sampled value differential protection [10].

In this paper, the differential protection model of bus sampled value with doubly-fed wind field incoming line based on the RTDS simulator platform is described. The influence of new energy entrance line on bus differential protection is evaluated according to the simulation.

2. The principle of differential protection of bus sampled values

Sampled value differential protection is generally judged on the basis of each sampled value. When the bus is in normal operation or outside the fault zone, the current value flowing into and out of the
busbar is zero. And all the branch currents on the bus are non-zero when internal fault occurs [11]. The basic criteria of percentage differential relaying are:

\[ I_d = |i_1 + i_2 + \ldots + i_n| \]  
\[ I_r = (|i_1| + |i_2| + \ldots + |i_n|) \] 

\[
\begin{cases} 
I_d \geq I_0 \\
I_d \geq K \cdot I_r 
\end{cases}
\]

Where \(i_1, i_2, \ldots, i_n\) are the currents of the branches on the bus. \(I_d\) is the differential current and \(I_r\) is the restraint current. \(K\) is the slope of the percentage differential characteristic. \(I_0\) is the differential current threshold. The sampled value differential protection action curve is as follows:

![Sampled value differential protection criterion curve.](image)

Figure 1. Sampled value differential protection criterion curve.

In this experiment, the sampled frequency is 1200 Hz and 24 sampled points per period. \(I_0\) is 0.75, and \(K\) is 0.5. According to the busbar protection safety and rapidity principle, \(R\) takes 18 and \(S\) takes 16. This means that in 18 consecutive determinations, the bus protection current element is opened until the sampled point satisfies the 16 times.

3. Simulation analysis

3.1. Simulation Experiments

The bus are 220kV double busbar subsection wiring. The ratio of transformer T1 is 0.69kV/35 kV, the ratio of transformer T2 is 35 kV /242 kV, the lines L1, L2, L3 and L4 are all 50km, and the line uses the Bergeron model. When the entire model is in balance, the wind field supplies active power 76MW, the system emits active power 4MW and each load absorbs 40MW active power. When the rotor current exceeds 1.5 times the rated value, DFIG uses a Crowbar protection circuit until the fault is over. The entire test model is shown in Figure 2.

![Bus protection circuit model with double-fed wind field incoming line.](image)

Figure 2. Bus protection circuit model with double-fed wind field incoming line.
3.2. Effect of fault type

Figure 3 shows the CT1 waveform of a single-phase earth fault (AG) at bus 1. Figure a) shows the fault current waveform. The fault current has a large zero-sequence current component and generates a large DC component.

![Figure 3. Single-phase earth fault (AG).](image)

Three-phase current with the same phase. Figure b) is a single-phase fault Fourier spectrum analysis and it can be seen that there is a larger DC component. Figure c) is the differential current IAO and the restraining current IAR. As can be seen from Figure d), the differential protection of the sampled value under this condition is reliable.

The a) and b) in Fig. 4 show that the sample d value satisfies the number of operation equations respectively when phase-to-phase fault (AB) and double-phase-to-ground fault (ABG) occur. When these two types of faults occur, they are all unable to reliably meet the operating criteria at the first moment.

![Figure 4. Two-phase fault (AB and ABG).](image)

The three-phase short circuit (ABC) situation is shown in Fig. 5. The reason why the a) graph appears is that the protection circuit is put in after a three-phase short circuit fault occurs. Both the stator and rotor side voltages are zero and the motor loses power excitation, so the stator and rotor currents eventually decay to zero. Due to the offset effect of the wind power current at the initial stage...
of the fault, the differential protection based on the sampled values does not satisfy the operating conditions at certain sampled points. As the wind current decays rapidly, the differential protection of the sample value tends to be stable [10]. Figure b) shows that at the beginning of this fault there were some sampled points that could not last 16 times to satisfy the action equation.

![Image](image1.png)

**Figure 5.** Three-phase short circuit fault.

3.3. **Effect of using Crowbar circuit**

Take the two-phase ground fault of AB as an example. Diagram a) of Figure 6 shows that the Crowbar protection circuit is not used during the fault. Figure b) shows the opposite. It can be seen from the above two figures that whether the Crowbar protection circuit is put into operation during a fault has a large influence on the differential protection of the sampled value. Using a Crowbar protection circuit during a fault will make the differential protection of the sampled value more reliable. Because the DC component decays faster with the protection circuit.

![Image](image2.png)

**Figure 6.** Effect of Protection Circuit on Differential Protection of Sampled Values.

4. **Conclusion**

When the double-fed wind farm has large capacity access to the power system, there may be some defects in the differential protection of the sampled value on the bus. When internal fault occurs in the bus, it has the following characteristics: 1. Due to the frequency offset characteristics of the stator current of the DFIG, the sampled value differential protection can’t work stably at the early stage. 2. From the point of view of the type of failure, the Single-phase earth fault has the least influence on the differential protection of the sampled value. 3. Using a Crowbar protection circuit during a low-voltage ride-through will make the differential protection of the sampled value more reliable.

**References**

[1] Yuan Rongxiang, Chen Deshu, Ma Tianjun, et al. Research on Current Differential Protection Principle of Sampled Value. Electric Power Automation Equipment, 2000, 20 (1): 1-3.

[2] Cheng Lijun, Yang Qixun. Research on Digital Letter Line Protection Based on Sampled Value
Algorithm. Power System Protection and Control, 2000, 28 (6): 4-6.

[3] Chen Deshu, Yin Xianggen, Zhang Zhe. Discussion on Some Problems of Differential Protection of Sampled Values. Electric Power Automation Equipment, 2000, 20 (4): 1-3.

[4] Ramar K, Ngu E E, Ishak N I N. A Simple Numerical Busbar Protection Technique Using Instantaneous Current Values // Asia-Pacific Power and Energy Engineering Conference. IEEE, 2012: 1-4.

[5] Hossain M, Leevongwat I, Rastgoufard P. Partial operating current characteristics to discriminate internal and external faults of differential protection zones during CT saturation. Iet Generation Transmission & Distribution, 2018, 12 (2): 379-387.

[6] Lei Ming, Wang Wensen, Kang Xiaoning, et al. Research on bus differential protection schemes that are not affected by asynchronous sampled. Power System Protection and Control, 2016, 44 (22): 96-101.

[7] Zhang Baohui, Li Guanghui, Wang Jin, et al. Influencing Factors of Fault Currents in Wind Power Integration into Power System and Its Impact on Relay Protection. Electric Power Automation Equipment, 2012, 32 (2): 1-8.

[8] Bi Tianshu, Liu Sumei, Xue Ancheng, et al. Fault transient characteristics analysis of double-fed wind turbines with low voltage ride-through capability. Power System Protection and Control, 2013 (2): 26-31.

[9] Pannell G, Atkinson D J, Zahawi B. Analytical Study of Grid-Fault Response of Wind Turbine Doubly Fed Induction Generator. IEEE Transactions on Energy Conversion, 2010, 25 (4): 1081-1091.

[10] Zhang Baohui, Wang Jin, Hao Zhiguo, et al. Impact of wind farm integration on relay protection (3): performance analysis for wind farm outgoing transformer protection. Electric Power Automation Equipment, 2013, 33 (3): 1-8.

[11] Wang Haiping. CSC-150/E Digital Bus Protection Device. 2011.