Analysis of Differential Current Protection Trip Event for UHV Transmission Line

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I. Introduction

This study analyzes a differential current protection trip event of a UHV transmission line by interpreting the on-site waveform curves and protection relay records. We use the power equipment parameter and system operation data collected to establish a power system electromagnetic transient simulation model by using the real-time digital simulator (RTDS). The trip event caused by the saturation of current transformer (CT) has thus been verified. The aforesaid analysis provides important information for the planning and design of differential current protection of a UHV transmission line and helps improve the protection performance of the transmission system.

A differential current function (short as 87L) trip event occurred in a UHV transmission system and the line section immediately tripped. Figure 1 is a single-line diagram of the trip. In this event, the 87L relays of transmission line X (87Lx) and transmission line Y (87Ly) operated and caused the circuit breakers (12、13、21、22、23、31、32) to trip. The substation maintenance staff found flashover traces and bird remains at the Disconnect Switchgear (DS) next to the circuit breaker 21 during inspection. The main cause of this trip event was judged that the birds stepped the grading ring above the Disconnect Switchgear (DS) by mistake and caused a phase A short circuit to the ground, and then caused 87Lx and 87Ly to trip circuit. However, the line to the ground short circuit occurs within the protection zone of 87Lx and outside the protection zone of 87Ly. No other but the transmission line X should be tripped. In this study, we aim to explore the reason of 87Ly operation in this accident.

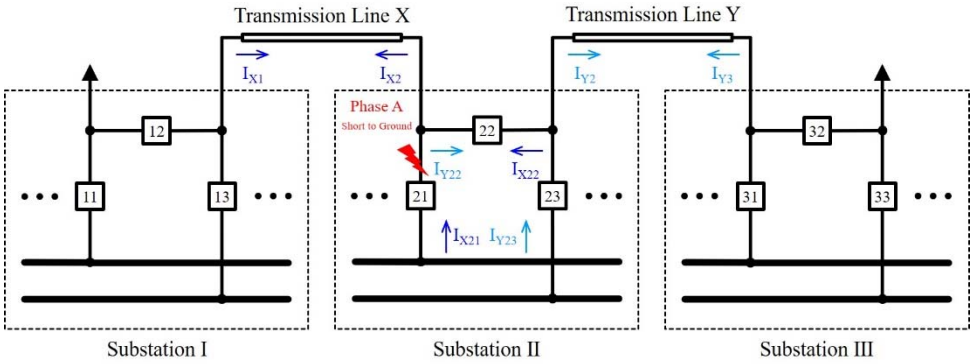


Figure 1：Single-line diagram for 87L trip event

II. Research method

Figure 2 shows oscilloscope event records at the substation II. The busbar phase A voltage V_A has a significant voltage drop and no other but the phase A current has a significant increasement. Therefore, it can be concluded that a ground fault occurred in phase A. Since I_{X2_A} waveform is not sine wave and has obvious distortion, it can be inferred that the current transformer (CT) is saturated. I_{Y2_A} has distortions and surge current at the end during short circuit.

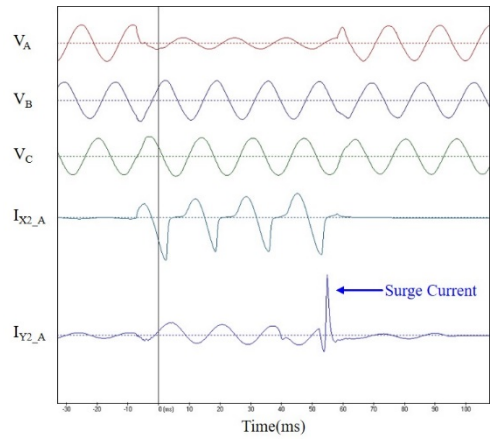
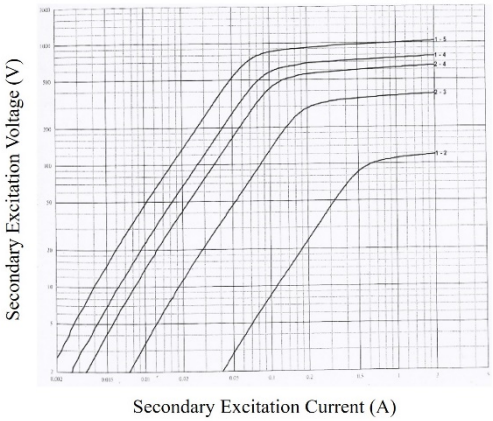


Figure 2：oscilloscope event records at the substation II

Since the current transformer (CT) is made of magnetic core material, it has the characteristics of hysteresis. In the application, there is a situation when the secondary side output current is distorted after saturation. When a short-circuit current occurs, there is a difference between the excitation characteristics of the parallel current transformers (CT) due to different residual magnetism. This may cause surge in the differential current summation.

The most important parameter of this event in the Real Time Digital Simulator (RTDS) model is the characteristic data of the current transformer (CT). Current ratio, secondary side impedance, load capacity, excitation characteristics, residual magnetism and other parameters are shown in Figure 3. The simulation results based on on-site oscilloscope and relay waveform records are shown in Figure 4, indicating that the short-circuit grounding event starts when the phase angle of A phase voltage is 135.6°. The circuit breakers at both ends of the transmission line X and Y tripped in sequence.



TAP	TAP 1-5
Turn Ratio	4000:5

Excitation Voltage (V)	Excitation Current (A)
98	0
145	0
260	0
400	0
700	0.1
760	0.1
880	0.1
900	0.1
920	0.2
1000	0.8

Figure 3：Current Transformer (CT) excitation curves

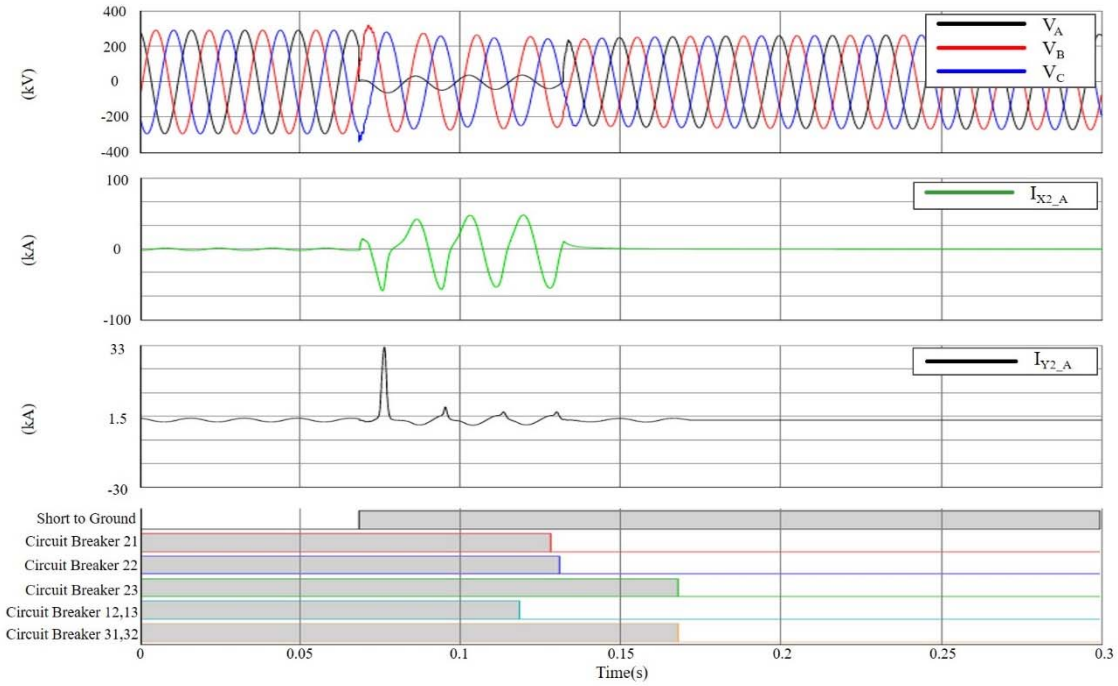


Figure 4：RTDS simulation result of this event

III. Conclusion

This article analyzes a trip event of the differential current protection of a UHV transmission line. We use the waveform recorded by the on-site oscilloscope and protection relay to analyze the trip event caused by the saturation of the current transformer (CT) and the electromagnetic transient simulation is performed with Real Time Digital Simulation (RTDS). To verify the consistency of our analysis, the simulation results have been compared with the event records. It not only shows a complete explanation of tripping root cause, but also provides important reference information for the planning, design and maintenance of UHV transmission line differential protection in the future.