Research on Electromagnetic Interference of Smart Device Acquisition Unit under GIS Disconnector Operation

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Abstract. With the continuous improvement of substation voltage level and the wide use of GAS insulated SWITCHGEAR (GIS), switching overvoltage, especially the very fast transient overvoltage (VFTO) caused by disconnector operation, has attracted more and more attention. According to the demonstration project of a new generation intelligent substation with the highest voltage grade (330kV) in operation in China, analysing the physical process of VFTO generation and propagation in high voltage substation by combining simulation calculation with test detection. Taking the electronic current transformer of intelligent secondary equipment as an example, its exploitation is established. We got the output signal waveform of the acquisition unit port under the action of VFTO by the high frequency transient model of the unit. By comparing the distribution parameters and the measured signal waveforms, the high frequency characteristics of the acquisition unit of the electronic current transformer under the action of VFTO are reflected. The results show that the EMI of the acquisition unit of electronic current transformer is in the form of pulse group. The amplitude of EMI is about 900V and the stable impact frequency is about 50 kHz. The impact frequency directly related to the arc reburning frequency.

1. Introduction
The traditional electromagnetic current transformers in substations have many problems such as complex insulation, dynamic saturation and large space occupation in ultra-high voltage intelligent substation. The electronic current transformer adopts Rogowski coil as the sensor. Compared with the traditional transformer, it has the advantages of simple insulation, small volume, light weight, wide dynamic range, no magnetic saturation, no resonance phenomenon, etc. It has been widely concerned and gradually applied in the industry. In a substation equipped with Gas Insulated Switchgear (GIS), when the isolating switch is operated, a very fast transient overvoltage (VFTO) with high amplitude,
steepness and high frequency is generated. [1-9], VFTO will not only cause great harm to the power equipment in the substation, but also cause large electromagnetic interference to the electronic transformer in the substation. Therefore, research on the electromagnetic compatibility of electronic current transformer under the action of VFTO is of great significance.

Domestic research on electromagnetic compatibility of electronic transformers has been done. The research on electromagnetic compatibility of electronic transformers in [10] is limited to experimental research and lacks the coupling mechanism analysis of primary side overvoltage. In [11], the black box model of the electronic current transformer is proposed. The transfer function of the electronic transformer is obtained by means of experimental fitting, and the mathematical model of the electronic transformer is established. However, the black box method needs to draw a lot of experimental data, and it is not universal for different types of transformers.

This paper analyzes the physical processes of VFTO generation and propagation in high-voltage substations. Based on the structural parameters of the electronic current transformer, the concentrated parameter and distributed parameter model of the Rogowski coil are established, and the simulation is carried out according to the established model. The signal waveform of the primary port of the transformer and the output of the sensing unit is obtained. The VFTO simulation model of the proposed electronic current transformer is verified by comparing the VFTO measurement results of the secondary port of the electronic current transformer of a gas insulated.

2. Simulation Research about VFTO

2.1. Simulation model

According to the outgoing line of a bus bar in a 330kV grade substation, a simulation model for separating switch operation is established. See Figure 1:

![Figure 1. Simulation model of VFTO generated by 330kV GIS isolation switch.](image)

According to the transmission characteristics of the internal and external transient wave processes of the GIS substation, it is equivalent to the transmission line model of the distribution parameters of the GIS internal bus conductors, and other component devices are represented by the equivalent parameters of the centralized parameters. For the isolating switch, it is equivalent to a part of the bus and the capacitance to ground (80pF) when closed, and concentrated capacitors (40pF) in pairs when disconnected. The arc model can be represented by a switch, and the switching of the switch is controlled by a logic judgment portion.

2.2. Simulation results

The voltage waveform of the isolator's load side is obtained by simulation, as shown in Figure 2. As shown in Figure 2, the maximum amplitude of overvoltage reaches 1.807p.u, and the average overvoltage amplitude is 1.3p.u. This does not take into account the residual voltage of the circuit, and the amplitude of the overvoltage is considered even greater.
Figure 2. Voltage waveform on the load side.

It can be seen from the figure that the frequency of arc reignition is getting higher and higher with the closing process, which is consistent with the theoretical analysis, which proves the correctness of the simulation model.

3. Rogowski Coil High Frequency Model

3.1. High frequency model of Roche coil

Since the parameters of the Rogowski coil are evenly distributed on the wire, it is not a form of concentrated parameters. Therefore, under the action of high frequency, when the Rogowski coil is modelled, similar to the transmission line, the parameters need to be dispersed over the entire coil. Unlike the transmission line, the induced voltage sources of the Rogowski coil are evenly distributed over the entire coil [12-15]. The equivalent model of the high-frequency coil of Rogowski coil is established in the form of transmission line as shown in Figure 3.

The differential equation of current and voltage is set up as follows: (1):

\[
\begin{align*}
\frac{d u(x)}{dx} &= -(dR_0 + sdL_0) i(x) + dU_0 \\
\frac{d i(x)}{dx} &= -\frac{1}{sdC_0} u(x)
\end{align*}
\]

(1)

3.2. Analysis of high frequency simulation results

The waveform shows that the output value of the Rogowski coil model is in the form of pulse group under the interference of VFTO, and the maximum amplitude is close to 1000V. Amplify a single impulse voltage pulse, see Figure 4.
4. Physical experimental analysis
In the process of isolating the switch, the secondary electromagnetic interference measurement system detects that the electronic current transformer acquisition unit has a high pulse signal at the moment of closing, and continuously oscillates in nearly half of the cycle, as shown in Figure 5. The secondary part of the sub-current transformer is disturbed during the closing process.

![Figure 5. Single pulse amplified waveform of measured data](image)

Comparing the simulation results, it can be seen from Figure 4 that the pulse waveform of the single electromagnetic interference obtained by the simulation is close to the trend of the measured data, and both are shock waveforms of the oscillation attenuation. The amplitude of the single pulse of the measured data is about 860V, and the stable oscillation frequency is about 47 kHz. This is close to the simulation value further proof of the correctness of the simulation model.

5. Conclusion
In this paper, the full-band simulation of VFTO is realized by using the arc model of logic judgment, and the electromagnetic interference simulation of the acquisition port of the electronic current transformer is obtained by using the high-frequency equivalent model of Rogowski coil. The following conclusions are drawn.

1) The isolating switch closing operation will generate 1.72 times the rated high-frequency voltage signal, the transient over-voltage signal frequency is up to 7 MHz; the high-frequency current signal has an amplitude of up to 4000 A.

2) The high-frequency equivalent simulation model of the electronic current transformer under the action of VFTO can well reproduce the electromagnetic interference received under actual conditions.

3) The results show that the isolation switch switching operation in 330kV GIS presents the form of pulse group to the electromagnetic interference of the collecting end of the electronic current
transformer. The amplitude can reach 900V, the stable impact frequency is about 50 kHz, the number of impacts and the arc The number of re-ignitions is directly related.

Acknowledgments
This work was financially supported by Key Research and Development Program of Shaanxi province of China (2017GY-031), and this work was also supported by natural science foundation of Hubei province of China (2018CFB189).

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