The Optimization Design of VFTO Measuring Method

Xue-geng CHEN*, Hui-bin SUI, Ying-chao LI and Shu-jiang LI
School of Electrical Engineering, Shandong University, Jinan 250061, China
*Corresponding author

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Abstract. Whether VFTO can be fast accurate measured becomes an important index of GIS substation equipment safety. The research in this article used the optical voltage measuring method, through the simulation results of single photon road to analyze the advantages and disadvantages, furthermore the double optical path method was put forward, and by the simulation the feasibility of optimization was proved.

Introduction

Gas Insulated Substation (Gas Insulated Substation, GIS for short) is widely used in nearly twenty or thirty years. But with the improvement of operating voltage, especially the development of the ultra-high voltage technology, electric power equipment insulation margin is reduced; the Very Fast Transient Overvoltage caused by switching operation which harms to electrical equipment causes the attention of people more and more [1].

The harm of VFTO is mainly shown in two aspects:
(1) The internal VFTO is harmful to internal insulation, specially to support insulators [2].
(2) External VFTO will be harm to the GIS external electrical equipment, such as transformer, overhead line insulation; it can cause the interference of secondary equipment and even damage them [3].

At present, the research on VFTO is not sufficient all over the world. Since the 1980s, there are many methods to be presented, such as Built-in probe method [4,5], Embedded electrode method [6], Calculus method [7,8] and Tube end shield method [9] etc. There are some measurements results have been achieved, but not ideal, the standard waveform of VFTO was not given. So the around 1 KHZ ~ 10 MHZ bandwidth measurement sensors of VFTO accurate measurement and further research are very necessary [10,11].

The Optical Measuring System of VFTO

The optical measuring system in this research is based on Pockels effect [12] to measuring VFTO.

The operation principle of the whole system is that the low voltage side sent DC light, which is uploaded to the optical sensor through a multimode fiber. The voltage signal in high side will modulate the DC light, now the light is not the DC light, it becomes the light which contains both the DC light and the AC light. The light with measured high voltage signal information is transmitted to the electronic circuit part of the low voltage side through multimode optical fiber, the light signal will be converted to the electrical signal and be transmitted to the acquisition card, finally, the measured signal is displayed by Industrial Personal Computer.

The Design of the High Frequency Signal Processing Circuit

The high frequency signal processing circuit often adopts single photon road measurement in traditional measurement system. This method just use photoelectric detectors, the partial detector is single beam output. The signal processing circuit consists of a filter circuit and an amplification circuit, in the case of long distance transmission, the circuit is needed to optimize by means of the theory of impedance matching [13]. When the load impedance and transmission line impedance is not equal, or connect two different characteristic impedance of transmission line, due to impedance
mismatch, it will produce reflection phenomenon, thus resulting in a decline in the power capacity and transmission efficiency of the transmission system, cannot obtain the maximum power load.

If you want the signal source give maximum power to achieve conjugate match, the input impedance of a transmission line and the internal resistance of signal source must be conjugate value. Assumes the source impedance is $Z_s = R_g + jX_g$, the input impedance of transmission line is $Z_{in} = R_{in} + jX_{in}$, The maximum power that signal source can output is:

$$P_{max} = \frac{|E_g|^2 R_m}{|Z_s + Z_{in}|^2} = \frac{|E_g|^2 R_m}{(R_g + R_{in})^2 + (X_g + X_{in})^2} = \frac{|E_g|^2}{4R_g}$$

To make transmission signal no reflection on the transmission line, that is to say, the signal energy is completely absorbed by the load, the load impedance and characteristic impedance of the transmission line must be equal. It means $Z_L = Z_0 = Z_{in}$. This is called impedance match. In this research, the design of impedance matching is to ensure that the circuit impedance of the power, line impedance and load impedance are all equal.

**The Design of Filter Circuit**

In the system, the band-pass filter is designed as anti-aliasing filter, its benefits for:

1. To prevent the frequency aliasing.
2. Can filter out the DC bias in front of the photoelectric detector.

There are two methods to realize the filter, active filter which uses active components (such as operational amplifiers and transistors) of and passive filter which use passive components (such as inductor, capacitor and transmission line, etc.). Active filter not only block unwanted spectrum, but also amplify the signal, however, its disadvantage is that the structure is complex, and the power consumption is consumed. There for, the passive filter is adopted in the design. The following figures are the designed filter and bandwidth test simulation results by (ADS simulation software):

![Figure 1. The design of filter.](image)

As shown in the simulation, the bandwidth of designed anti-aliasing filter is 900Khz~6Mhz.
The Design of Single Photon Signal Amplifying Circuit

This design uses the AD8003 operational amplifier, which is current feedback operational amplifier; Its gain bandwidth product is not limited, but mutations will occur at the maximum of amplification frequency. The AD8003 operational amplifier can boost the signal of up to 1650 MHZ. ADS simulation software is applied in circuit simulation.

Figure 3. The simulation diagram of operational amplifier circuit.

Figure 4. The result of magnification simulation.

Simulation results show that in low frequency the output voltage amplitude and the input voltage amplitude meet magnification relation, thus this circuit design is reasonable, can realize zoom function.

The software named ADS2008 is used to equivalent the entire system, the figure 5 is equivalent circuit of single photon signal measurement system. To simulate system under the circumstance of impedance matching circuit, signal input voltage is set to exchange 30 mv, the impedance of the voltage source is set to 50, and the transmission line and load impedance are set to 50, simulation results are shown in the figure 6:
Figure 5. Single photon signal measuring equivalent circuit.

Figure 6. Input/output amplitude-frequency figure.

Operation amplifier part of the measurement circuit would amplify the signal by 4 times, but through the waveform diagram, the output voltage changes in the frequency range is very large, which makes the signal acquisition is inaccurate and affect the accuracy of the results.

The Design of Dual Optical Path Signal Measurement

Dual optical path signal measurement method uses two photoelectric detectors. Dual optical path signal test using this nature that the direct part of optical signal is the same, AC phase difference is 180 degrees, the two-way signal to do subtraction, do pretreatment in analog part, it can greatly reduce the low frequency part of signal, the rest will do digital filter in the rear of the system to eliminate the low frequency component.
The figure 7 is the design of dual optical path signal detection circuit:

Figure 7. Dual optical path measurement system equivalent circuit.

In the design, there are two sources to power supply circuit, voltage of ac 30 mv, phase Angle 0 and 0 v, the phase Angle of 180 respectively. Signal amplifying circuit magnification is set to 6 time, the load impedance is set to 50 $\Omega$, now the impedance matches. From the ADS simulation, we get the following waveform shown in Figure 8:

Figure 8. Input/output amplitude-frequency figure.

From the above, in the designed frequency range (900 KHZ ~ 6 MHZ), amplitude is basically stable at 180 mv, which is six times of the input voltage, meets the magnification relation. The signal measurement method is more stable and accurate than the single photon road method.

Summary

Main purpose of this article is to optimize the existing VFTO design, though the study on impedance matching and reflects to prove the importance of the impedance matching and its impact on the signal transmission theoretically. It verified that signal acquisition is inaccurate in the case of impedance mismatching. For single photon path method, the simulation found that the measured results are not ideal, the output voltage waveform changes in the frequency range is very large and unstable, prone to distortion, the signal acquisition precision is not high. And thus the improvement scheme is put
forward, which is the dual optical path method. Simulation proved that the dual optical path system has the advantages of low noise, stable output signal, and high precision.

References


