Research on High Voltage Capacitor Voltage Drop Device

Ling Zhang, Te Ba and Xiao Luo

State grid changji electric power supply company of Wulumuqi Province
Xinjiang, China.
Email: Jun21138303@qq.com, zym_ym_xj@163.com, 413855933@qq.com

Abstract. With the advent of smart grid, smart transmission lines as an important part of smart grid gradually entered the construction. In view of this, installing various testing equipment on the transmission line tower is the basic work of building intelligent transmission line. However, limited by geographical conditions or insulation conditions, there are few low-voltage power supply near the transmission line towers. It is a big problem to supply power to the low-voltage detection equipment on the towers. In this paper, a new method of capacitive buck charging for transmission line towers is proposed. A special high voltage line capacitor and voltage transformer are used in series to extract energy directly from the high voltage line. The insulator string is used as the insulation support of the overvoltage of the transmission line, and the line capacitor and voltage transformer are connected in parallel. Stable energy output is obtained to achieve reliable power supply for transmission line tower monitoring equipment. However, the power supply will inevitably suffer from lightning strikes if it is exposed to nature for a long time. Therefore, it is of great practical significance to study the transient characteristics of Lightning Overvoltage in capacitor power supply system and to study its protection technology to ensure its safe and reliable operation.

1. Introduction

High-voltage overhead transmission line is the most extensive power system coverage, operating environment is complex, the external factors are frequent power links, its operation status plays a vital role in the safety and reliability of the power system, once the failure will bring enormous impact and loss to production and life, therefore, the urgent need for transmission. On-line and real-time monitoring of the running state of the power line can reflect the running state of the line in time so as to take preventive measures to minimize the loss. With the advent of smart grid, smart transmission line as an important part of smart grid gradually enters the vision of builders, and becomes the inevitable trend of transmission line development. Installing various detection equipment on transmission line tower is the basic work of building smart transmission line. These testing equipments are usually electronic equipments, which need power supply to work. Their commonness is: the power demand for power supply is very small, usually several to dozens of watts; Low voltage, commonly used 5V, 12V, 24V; With intermittent power demand, the power supply is mostly in a low-power state for most of the time, working in a short time in a high-power state. However, limited by geographical conditions or insulation conditions, there are few low-voltage power supply near the transmission line towers. It is a big problem to supply power to the low-voltage detection equipment on the towers. Current transformer power supply from the line is difficult to transfer to the tower. At present, the mainstream method of power supply to tower monitoring equipment is to install solar cells or wind turbines on the tower, or both, plus storage battery to maintain power supply when there is no wind or sunlight, but solar panels. And the battery life is short, can not meet the requirements of long-term fault-free operation, line tower is very scattered, the promotion of large areas of use, is bound to cause...
huge maintenance workload and maintenance costs in the future, restricting the progress of intelligent transmission lines. In view of the above problems, this paper presents a capacitive voltage-reducing method for power transmission line towers. A special high-voltage line capacitor and voltage transformer are connected in series directly from the high-voltage conductor. Insulator strings are used as the insulation support of the overvoltage of the transmission line and are connected in parallel with line capacitors and voltage transformers. This method can obtain stable energy output to realize reliable power supply for tower monitoring equipment of transmission lines. After adopting this power supply, the cost of the power supply part is estimated to be about 10-30,000 yuan (depending on the voltage level), which will greatly save the design cost of the power supply part of the tower monitoring system, and can avoid maintenance and operation for a long time. Thoroughly solve the problem of tower power collection. Intelligent video surveillance system is used to test the effectiveness of the power supply. The surveillance system can automatically sense moving objects around the tower, such as people, livestock, birds and so on, send alarm signals to the control center, and also send out alarm sound and light locally, and record the objects. The video surveillance system can be controlled remotely, and the image can be displayed in the control center in real time or on the computer through the network. The functions of theft-proof, tower foundation surveillance, vegetation surveillance and on-site construction command can be realized finally.

High voltage capacitor buck is a traditional way of power supply, but there is a problem of capacitor overvoltage in the process of its utilization. If the operating voltage is too high, it will endanger the equipment and safe operation. There are many factors that cause steady-state voltage rise, which will be analyzed below.

2. Overvoltage Analysis

A transient calculation model is established according to the equivalent circuit and parameters of each part of the capacitor acquisition system. C is capacitor value of high voltage line capacitor. R1 and L1 are voltage transformer primary winding resistance and inductance, R2 and L2 are Residual winding resistance and leakage inductance. Lm is Nonlinear inductance for excitation branch. Rx is Equivalent resistance of power conversion circuit. U1 is The high frequency voltage acting on the primary side of the power receiving system.

According to the simulation calculation model of 110 kV capacitor buck charging system, the high voltage line capacitor is directly prototype and the total capacity of series capacitor is 596pf, The equivalent resistance of subsequent power conversion circuit is260ohm, Winding parameters of voltage transformer: R1=4530ohm, L1=28.3H; R2=2.4ohm, L2=3.73H.

In this paper, the voltage characteristics of capacitive power system under steady state are analyzed first. Applying alternating current voltage to the primary side of the power supply system, the voltage value of the secondary side of the voltage transformer in the power supply system is obtained by simulation calculation. In order to accurately simulate the actual operation state of the power supply system, alternating current power is selected in the simulation. The AC voltage amplitude rises from 10kV to 127kV, rated frequency is 50Hz, step size is set to 10. 6s, the termination time is 0.1s.

| U1/kV | U2/kV | U3/V | U1/kV | U2/kV | U3/V |
|-------|-------|------|-------|-------|------|
| 4.9   | 1.52  | 33.4 | 55.6  | 8.43  | 182.6|
| 10.6  | 2.13  | 46.3 | 60.7  | 9.14  | 197.4|
| 14.9  | 2.71  | 59.5 | 63.8  | 9.82  | 216.3|
| 19.0  | 3.54  | 77.4 | 70.4  | 10.05 | 220.2|
| 25.7  | 4.26  | 91.3 | 73.5  | 10.06 | 219.4|
| 30.5  | 4.95  | 107.5| 80.7  | 10.06 | 220.5|
| 35.8  | 5.63  | 121.5| 91.3  | 10.07 | 220.6|
| 40.2  | 6.44  | 140.3| 102.8 | 9.99  | 219.3|
| 46.8  | 7.06  | 153.2| 113.9 | 10.08 | 221.5|
| 50.4  | 7.75  | 168.4| 126.3 | 10.04 | 220.3|

Table 1. Output voltage chart
The diagram shows that when the power frequency voltage is 63.5 kV applied to the primary side of the power supply system, the voltage peak value of the secondary side of the voltage transformer can be obtained. The voltage on the secondary side of the voltage transformer is 216.3V in the power frequency AC experiment of the power system. The error between the simulation results and the experimental results is 1.07%.

3. Analysis of Overvoltage Simulation Results
In order to study the overvoltage level of capacitor buck system, the transient process of lightning directly acting on the system is simulated by ATP-EMTP. Voltage parameters of primary and secondary side of voltage transformer can well reflect the overvoltage level of power system and the selection of overvoltage protection measures. Therefore, the lightning overvoltage simulation obtains the voltage, current, waveform and other parameters of the primary and secondary side of the voltage transformer under different high voltage amplitudes. In the simulation, Heidler shock wave power is selected as the power supply model. The wave front time is 2.6ps, the wave tail time is 501as, the wave impedance of the electric channel is 300Q, the step size is 10S, and the calculation termination time is 0.1s.

When the standard high voltage acts directly on the power system, the high voltage is added to the primary side of the voltage transformer almost all through the high voltage line capacitor, and the voltage waveform will oscillate due to the role of inductance and capacitance in the circuit. The amplitude of high overvoltage on the secondary side of the voltage transformer will increase sharply with the increase of the peak value of high voltage impulse on the primary side of the system. When the peak value of high voltage reaches 1700kV, the positive peak value of voltage on the secondary side of the voltage transformer is 3919V, the negative peak value is 1310.2V, and when the peak value of high overvoltage is 100kV, the voltage transformer II will increase sharply. The positive peak value of secondary voltage is 6158.4V and the negative peak value is 12059 V, that is, the highest overvoltage can reach 4-6 kV, which greatly exceeds the lightning impulse tolerance level of the secondary side of the voltage transformer, and will have a serious impact on the subsequent power conversion circuit.

4. Voltage Transformer Access to Lightning Arrester Protection
By calculating the high voltage level of the power system, it is known that the high voltage directly acting on the power system is added to the primary side of the voltage transformer through the high voltage capacitor, and the overvoltage transmitted to the secondary side of the voltage transformer will greatly exceed the high voltage impulse withstanding voltage of the voltage transformer. Therefore, it is necessary to install oxide lightning protection. The device is used for overvoltage protection of power system. As one of the main lightning protection devices, lightning arresters should be selected according to the protected equipment. Three principles are followed in selecting the arrester: determining the continuous operating voltage of the arrester according to the highest voltage acting on the arrester; selecting the nominal discharge current of the arrester according to the lightning discharge current amplitude (estimated) of the arrester, generally there are six grades: 1kA, 1.5kA, 2.5kA, 5kA, 10kA and 20kA. According to the requirement of insulation coordination coefficient, the protection level of lightning arrester is determined according to the rated lightning impulse withstanding voltage and operating impulse withstanding voltage of the protected equipment and considering certain insulation margin. The protection level of the oxide arrester is determined by the residual voltage, that is, the maximum residual voltage allowed under the high electric impulse current of the arrester.

The power supply protection includes overvoltage protection and overcurrent protection. When the high-voltage line fault and lightning impulse produce surge current, which will lead to insufficient output power of the subsequent circuit, can not guarantee the normal operation of the detection equipment. Estimation of the maximum inrush current: If the maximum lightning voltage or internal overvoltage is 700 kV and the equivalent frequency is about 1 MHz, the maximum inrush current is obtained. During overvoltage, the inductor raises the voltages of ACA and ACB, causing the varistor to act, and most of the surge current flows through the varistor. When suffering from lightning impulse, the high frequency of lightning wave causes short circuit of high voltage capacitor, which is equivalent
to lightning wave acting directly on voltage transformer. This is absolutely necessary. In this design, 10 kV lightning arrester and air gap are connected in parallel on the primary side of the voltage transformer, which can double guarantee the damage caused by lightning impulse to the electrical equipment.

5. Conclusions
In this paper, the design of high voltage capacitor and voltage drop power supply is presented, and the power supply system based on this method is completed. The test results show that the system is stable and reliable, and can provide stable and effective power support for most high-voltage side measuring equipment.

6. References
[1] Aderhold J, Davydov V Yu, Fedler F, Klausing H, Mistele D, Rotter T, Semchinova O, Stemmer J and Graul J 2001 J. Cryst. Growth 222 701
[2] Dorman L I 1975 Variations of Galactic Cosmic Rays (Moscow: Moscow State University Press) p 103
[3] Caplar R and Kulisic P 1973 Proc. Int. Conf. on Nuclear Physics (Munich) vol 1 (Amsterdam: North-Holland/American Elsevier) p 517
[4] Szytula A and Leciejewicz J 1989 Handbook on the Physics and Chemistry of Rare Earths vol 12, ed K A Gschneidner Jr and L Erwin (Amsterdam: Elsevier) p 133
[5] Kuhn T 1998 Density matrix theory of coherent ultrafast dynamics Theory of Transport Properties of Semiconductor Nanostructures (Electronic Materials vol 4) ed E Schöll (London: Chapman and Hall) chapter 6 pp 173–214
[6] Simulation Study on Damage of 10kV Voltage Transformer [J]. Power System Protection and Control, 2012, 40 (17): 51.55
[7] He Youzhong. Research on power supply of high voltage on-line monitoring equipment [D. Chongqing University, 2011
[8] Dondi D, Bertacchini A, Brunelli D, et al. Modeling and Optimization of a Solar Energy Harvester System for Self-Powered Wireless Sensor networks[J]. IEEE Transactions on Industrial Electronics, 2008, 55(7):2759—2766.