Anti Theft And Monitoring System Of Street Lamp Power Cables

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***Abstract*: A novel anti-theft and monitoring method of streetlamp power cables is presented in the paper. The method is based on capacitance current resonance measurement principle. A current signal with frequency varying is injected to the street lamp power system, then the resonance frequency can be found the equivalent capacitance and the length of the cable can be calculated. Whether the cable is stolen or not can be judged, and** the **fault location can be calculated. The novel method is no necessary to add equipment to the end of street lamp power cables, and it's not influenced by power transformer types and the cable length. Simulation experimentations are carried out. Simulation results show that the method is simple and correct.**

Keywords: Street lamp cables; Anti theft and alarm system; Capacitance current; Resonance measurement

INTRODUCTION

At present, the metal resources supply is very tensional with the society develops quickly. The thief pays more attention to the cables because of its characteristic of low transmission voltage, dispersed layout and high containing Cu.The public utilities are brought to a great deal of troubles and danger. Take the case of Changsha, the economic loss due to cable stolen was from 6 million to 8 million RMB every year since 2005. Meanwhile, it will cause the street lamp not to work and bring inconvenience to the people' lives.

There are four main methods of anti theft and detection of the cable, such as leakage current measurement method, working current measurement method, DC impedance measurement method, power line carrier method. The first method is that the leakage current is produced artificially, and the leakage current is detected in switch box. This method is affected easily by the climate condition and it is operated only when the street lamp is on. The second method is also operated when the light is on, and the working current is affected by the voltage fluctuation. The third method can be operated when the light is off, but it needs to installed DC load to the end of street lamp cable.

In addition, considering the cables buried under ground suffer from heavy rain, its DC impedance is not infinite. Therefore it has a high false alarm rate. The fourth method needs to install power wave carrier receive equipment to the end of the cable, its cost is very high. It is affected by the capacitance of the cable, so its transmit range is limited. And this method can't detect the location of the breaking line.

In order to improve the monitoring precision and extend the monitoring range, a novel anti-theft and monitoring method of street lamp power cables is presented in this paper. The capacitance of the cable and the load can be calculated through the resonance measurement method, and then the length of the cable can be calculated. Whether the cable is stolen or not can be judged, and the location of the breaking line can be detected. The method is not affected by the transformer type, its detection range is not limited, and it still can work when the street lamp is off. The simulation results show that the method is simple and correct.

THE CIRCUIT OF THE STREET LAMP AND ITS SIMPLIFIED FIGURE

To resolve the problem about integrality of the cable when the distribution lines switch off, the circuit feature of street lamp is analyzed, and electrical component is instead of the street lamp which is off.

In the street lamp power system, the street lamp is used by high voltage sodium lamp with inductive current limiter. The principle diagram is shown in Fig 1.

High voltage sodium lamp is a kind of lamp which works as high intensity gas discharge.

The working condition of the lamp is not stable because of its negative resistance when it is connected into power system singly. In order to balance the negative resistance, the lamp must be in series to a positive resistive circuit. The component is called current limiter whose function is to stabilize the current. Inductive current limiter is used usually. It is shown in Figure 1. As *L* and *Cz*, *Cb* is for the compensation capacitor about the compensation of lamp's reactive power. In Figure 1, the lamp can be equivalent to a capacitance *Cn* in open circuit condition.

$$C_n = C_b + C_z \qquad (1)$$

Where, *Cb* is a compensate capacitance. *Cz* is a capacitance of the current limiter. Because both of *Cb* and *Cz* are known values, *Cn* is known.

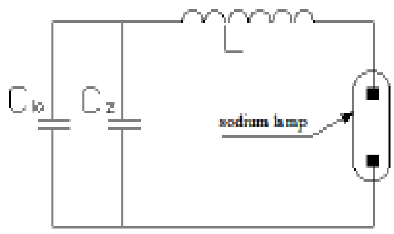

Figure 1. The principle diagram of high voltage sodium lamp

Through above analyzing, the equivalent circuit can be simplified as Figure 2.

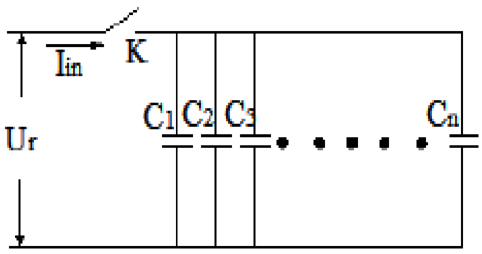

Figure 2. The simple diagram of the street lamp system in open circuit condition

As shown in Figure 2, the breaking location can be calculated using the circuit capacitance value detected. It is a theoretical basis of the novel anti-theft and monitoring method.

THE PRINCIPLE OF ANTI-THEFT AND MONITORING

A. Capacitance current measuremen principle

A current signal with frequency varying is injected to the system through an inductor which is in series connection or parallel connection with the street lamp circuit. The circuit capacitance can thus be calculated using the resonance frequency. The measurement principle circuit is shown in Figure 3.

L is the parallel connection inductance, *C* is the measured capacitance, Iin is the current signal with frequency varying, *U* is the voltage signal return, *R* is the resistance of measurement circuit. A current signal with frequency varying is injected to the system, then the return voltage signal *U* can be detected. Comparing phase difference between the current signal and the return voltage signal, when it is zero (that is resonance), this signal angular frequency (ω_0) is the resonance angular frequency of the system. Based on resonant principle, we can derive:

$$C = 1/(\omega^2 L) \qquad (2)$$

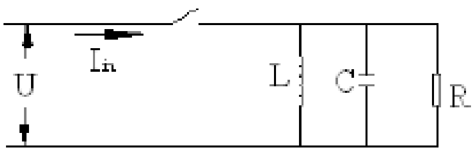

Figure 3. The principle diagram of capacitance current measurement

B. Anti-theft and monitoring system of the single-phase street lamp

The street lamp discharging needs more than 220V to be triggered. When the breaker switches off and the voltage on the circuit is no more than 20V, the street lamp can't be lightened. Therefore the circuit is open. The electric circuit can still be equivalent as shown in Figure 2.

In Figure 2, an inductance with constant value L and a resistance with constant value R are parallel connected to the system. The circuit of the single-phase street lamp system can be shown in Figure 4. L is for the definite value inductance and R is for the definite value resistance. Point A is the open circuit fault point.

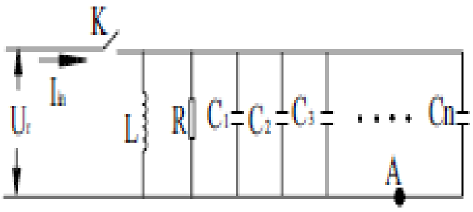

Figure 4. The circuit diagram of the single-phase street lamps system

In the street lamp power system, the lamp and the current limiter for every branch have the same type, so the equivalent capacitance is also the same. Assume that C0 is the equivalent capacitance of the each lamp. The formula below can be derived:

$$C_1=C_2=C_3=\ldots\ldots C_n=C_0 \qquad (3)$$

The total capacitance is as follow:

$$C=n^*C_0 \qquad (4)$$

From formula (2) and formula (4), we can derive:

$$N=1/\ \omega_0^2 LC_0 \qquad (5)$$

From formula (5), we can find that the resonance frequency ω_0 is just related to number of when the lamps n, so when the resonance frequency ω_0 changed, it means that the number of the lamp n changed. As shown in Figure 4, when fault happens at point A, the capacitances on the right side of point A are isolated. The resonance frequency ω_0 can be detected, and the number of the lamps n1 can be calculated. Then the fault point A is between the towers of n1 and n1+1. The problem of fault location is resolved.

C. Anti-theft and monitoring system of the three-phase street lamp

In practice, the street lamp power supply system is used by the three-phase four-wire system. There are four cables in each cable channel. When the cables are stolen, the four cables are cut off together. So the anti-theft and monitoring system of the three-phase street lamp is designed as follow:

The three-phase street lamp system is used by inspection tour method. A, B, C three phases are inspected periodically by single-phase inspection method. Under the same period, the capacitances of A, B, C three phases decrease at the same time, and the resonance frequency of each phase changes, it means that the cables are stolen, the anti-theft and monitoring system alarm. Then the fault point can be found by the formula (5).

D. False alarms exclusion

The lamp cables can be considered to be stolen when the capacitances decrease through analysis above. However, there are another two kinds of conditions in which the capacitances also decrease, the false alarms are produced. The false alarms and its exclusion are introduced as follow:

1) The capacitance damage

With the compensate capacitance of the power line and the capacitance of the current limiter aging or breakdown, the capacitance value will decrease, the false alarm is produced.

2) Single-phase break circuit

When the single-phase break circuit is happened, the voltage can't be detected and the false alarm will be produced.

In the false alarm condition above, it's just that the single phase capacitance changes, which only affects the resonance frequency of the fault phase, without influence of the resonance frequency of the sound phase. So the capacitance damage and the single-phase short circuit are judged to be happened when the resonance frequency of single-phase or two-phase change.

SIMULATION RESULTS

A. Simulation system and its parameters

In order to verify the accuracy of current measurement of the resonance circuit capacitance detection, a simulation model which is based on Matlab / Simuink platform has been constructed, the procession of the Measurement of single-phase is simulated. In accordance with the actual situation of street lamp system in the city of Changsha, a simulation model is built as shown in Figure 5. The cable length is 800m, and it is separated by 40m to connect a street lamp every time.

The equivalent capacitance of high-voltage sodium lamp (including ballasts and flip-flops) has been simulated as C in Figure5. The dashed border is for a basic unit (including two cable inductance and capacitance equivalent of a street lamp), K-switch analog the open points, 12 units are in front of the open points, 8 units behind the open point. *n1* is the number of lamp which is connect to the circuit when the switch is closed, *n2* is the number of lamp which is connect to the circuit when the switch is opened. *l* is for inductance which connect to the two adjacent cables between the poles of the inductors. *r* is for the resistance of current frequency signal source. *L* is an added inductance value; *R* is an added resistance value. All the technical parameters in the line of the Simulation Model are shown in Table I.

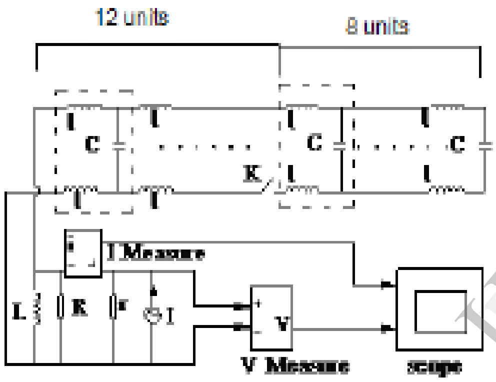

Figure 5. Simulation model

TABLE I. THE PARAMETER OF CIRCUIT SIMULATION

l	10uH	C	50uF
I	1A	r	$10^{9}\Omega$
L	50mH	n_1	20
R	10Ω	n_2	12

B. Simulation results

Comparing phase difference between injection current and return voltage, when it is zero (that is resonance), this signal angular frequency is the resonance angular frequency of the system. Simulation of both switch closing and switch opening show that fa=22.51Hz, fb=29.06Hz are resonance frequency of pre-break and post-break. When the system is in resonant condition, waveforms of the injection current and return voltage are shown in Fig.6 and Fig.7.

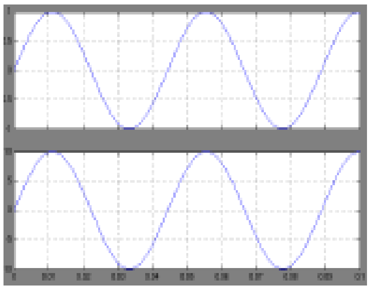

Figure 6. The injection current and returns voltage waveform when switch K is closed and f_a=25.51Hz

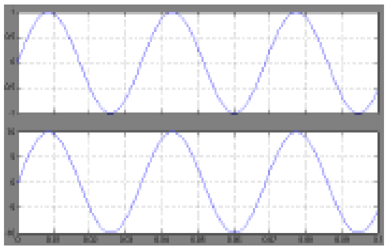

Figure 7. The injection current and returns voltage waveform when switch K is opened and f_b=29.06Hz

According to formula (2), the capacitance in condition of the normal state and switch K opened are C1=9.998*10-4F and C2=5.999*10-4F respectively. According to formula (5), n1 approximately equal 12. Fault occurs between the 12th tower and the 13th tower, which is the actual fault point.

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C. Error Analysis

Simulation results show that there is error between equivalent capacitance of the calculated circuit according to resonance frequency and the actual capacitance, the reason is that the effect of cable inductance is neglected. Considering the capacitance of the street lamp system increase by 50uF when the length increases by 40m. The tiny error doesn't affect the range of fault location.

CONCLUSION

The monitoring scheme is to measure the equivalent capacitance of the street lamp cable according to the capacitive current resonance measurement method, and the cable length can then be calculated. The street lamp cable cut and stolen can be judged by the length, and the fault point is located. Theoretical analysis and simulation results verify the method. The method isn't affected by transformer types and cable length. Cable anti- theft productions are in progress. They will be applied in the Changsha lamp power system.

REFERENCES

[1] YE Yuanguo, LIAO Guowu. Study on Low-voltage power distribution cables security. [J]. (Journal of South China Normal University (Natural Science Edition), 2000(5), 34-36
.
[2] FANG Bo, QING Dawei.The Burglar Alarn System of Power Table. Technology of Electrician[J].2007(I),30-31.

[3] ZHOU Binfa, LI Tao, LIN Tao. Study on Anti-theft alarm system of Street lighting cable. Lighting monitoring [J]. 2005(4).23-24.

[4] LIN Lisheng. The circuit design of anti-theft alarm system for general power cable. Hydraulic engineering[J]. 2007(3).59.

[5] WANG Jun. The line laying of buried cable and an ideal anti-theft device Engineering technology[J].2003(23).275-279.

[6] SHEN Weiguo,WANG Weisheng.The Principle and Application of the Inner Starting High Pressure Sodium Lamps .Photonics Technology,[J].2003(23).275-279.

[7] ZENG Xiangjun,YI Wentao,LIU Zhanglei,et al.A Novel Technique of Capacitive Current Resonance Measurement with Signal Injected for Distribution Networks.Automation of electric power systems,2008,4(32):77-80.

[8] LIU Li,SUN Jiezhong.A new method to measure capacitance current in distribution network.Power system technology, 2001,25(5):63-65

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