Research on the Comprehensive Energy Consumption of the Cable of the Radio Frequency Acquisition Terminal

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Abstract. Promoting two types and two transformations, and achieving two transformations is a medium- and long-term development strategy for cable implementation, and is committed to a smart, efficient, reliable, and green direction. The biggest difficulty in the research of distribution cables is the research of cables, and it is also the key point that affects the reliability of power supply. The article discusses the application of wireless radio frequency technology to the on-site identification of cables to improve the efficiency of on-site cable positioning and fault handling, improve power supply reliability, Cable intelligent, efficient and reliable cable research methods use radio frequency technology identification methods to collect on-site cable and equipment attribute information, establish on-site underground cable information identification network, establish data electronic ledger in the background, and then enrich the cable GIS system data , Analyse the comprehensive energy consumption of the cable, and provide a scientific research reference direction for the distribution network cable research.

1. Introduction
The working principle of the heating cable ground radiant heating system is to lay the special heating cable in the cushion under the floor of the room. When the heating cable is energized, its working temperature is 40 °C ~ 60 °C. A new type of heating system in which electric energy is converted into heat energy by using a heating cable as a heating element, and the heat is transferred to the room to achieve the purpose of heating. In the heating system, the conversion of electrical energy into thermal energy has a thermal efficiency of more than 99%, of which radiant heat exchange accounts for more than 60% of the total heat exchange [1].

Due to the rapid development of the regional economy, the changes in the geographical environment caused by municipal construction, housing construction, roads, greening, and various pipeline constructions, the original cable markers have been missing or the fonts are obscure and difficult to recognize, and they cannot be reused. To identify the cable path or identify the cable. In the transformation of cable lines and the search for cable faults, due to historical reasons and the impact of local geographic environment, there is much water and silt in the cable trenches, and some cables are arranged in a cross. A cable should be determined in a complex environment, although cables can also be used Identifier or other locator to search, but due to the incomplete drawings of the original data, the missing or ambiguous cable marking, it takes a lot of time and labour, and the detection equipment
is interfered by external conditions, which is prone to large errors. In view of the above, the introduction of a cable intelligent research system to improve the research level has become an urgent task for the power supply department.

2. Analysis of the status quo of power underground cable operation and maintenance
The power cable coverage rate has reached 48%, but the operation and maintenance personnel of the class office have encountered great difficulties in the research and operation of the underground cable. The first is the poor preservation of the drawings and data, which leads to many unclear directions, which leads to the cable fault investigation. Difficult, which seriously affects the reliability of power supply; followed by cable laying methods except for the open trench, most of them are laid in the form of pipe jacking, draining, direct burial, etc., so that some areas are unclearly marked and vulnerable to external damage. In 2014, there were 95 power cable external force destruction incidents; and the lack of power cable drawing data also led to the failure of the usual operation and maintenance research, which led to the spread of hidden defects and even failures.

2.1. Missing data in cable wiring diagram files
The degree of informatization in the research of cable lines is low, and the design and research of underground power assets are based on traditional paper-based record keeping. Due to historical reasons, part of the cable wiring diagram file data is missing, the old urban cable has been buried for more than 10 years, and the cable wiring diagram file data is already in a missing state. The basic data of the data is not comprehensive, and it is difficult to share or provide information externally.

2.2. The cable lacks geospatial information such as depth and direction
Due to various reasons such as history and technology, many cable data have been lost or the information is incomplete, especially the spatial information such as cable depth and direction is generally lacking. There are no accurate and complete cable path drawings. The operation and maintenance team mainly depends on the few remaining paths. "Spot-point" inspection is carried out at the point, and hidden danger points of external damage are difficult to find. The data of the cable buried depth of the pipe jacking section is inaccurate. The historical pipe jacking data is inaccurate due to high or low pavement filling. The type of pipeline at the intersection is concentrated (water pipe, gas pipe, street lamp, etc.), which is easily caused by blind construction by external unit’s External damage. A lot of manpower and time are often used to find the cable path in the emergency repair. The cable fault detector is often used to grasp the distance of the fault point, but the cable path is not clear, which makes it impossible to find the fault point in time.

2.3. The channel data is incomplete, important information such as laying method is not built
There is no geographic information account for establishing cable channels, important data such as cable laying methods, cable trench tube sizes, tube holes, cable wells and other pipelines are not built, and various basic information and operational information research methods are lagging behind. It is difficult to update the data and query statistical analysis by means of forms and drawings, which is not conducive to further strengthening the informationization and lean research of cable equipment.

2.4. GPS on-site positioning is difficult and the accuracy is not enough
GPS positioning is affected by many factors, and its positioning accuracy is difficult to meet the requirements of fast cable search and precise positioning. Especially in urban areas where distribution network cables are densely distributed, the GPS positioning solution is slow and the accuracy is low due to the blockage of tall buildings and trees. GPS has poor repeatability of positioning data, and its coordinates cannot be used as the basis for information system retrieval [2].
3. Establishment of cable energy consumption model

3.1. Working principle

The heating cable is generally serpentine, as shown in Figure 1. Firstly, lay coarse gravel asphalt concrete or similar materials in the road structure layer, then lay a heating cable of a certain power according to the process requirements, and then lay a thickness of about 50mm the gravel type asphalt concrete. The heating cable system used for road snow melting and ice melting uses intermittent operation. The literature [3] recommends that the general pavement power is 250-400W / m2. The mechanism of using the heating cable to melt snow and ice is: After the power supply is connected, the heating cable generates heat and the temperature rises. At the same time, the heat is transferred to the ice and snow layers through the asphalt concrete to make it absorb heat and heat up, so as to achieve the effect of melting snow and melting ice. Under the control differential equations and boundary conditions, the temperature field or temperature distribution inside the object is solved.

![Working principle of heating cable](image)

Figure 1. Working principle of heating cable

3.2. Governing equation

Due to various complex factors, the heat transfer of the heating cable in the road structure layer is difficult to solve. In order to simplify the problem, the following assumptions are made for the calculation model shown in Figure 2: 1) Because the length of the cable is very large compared to the cable spacing Large, the temperature field changes very little in the direction of the cable, so ignoring the heat transfer in this direction can be simplified to a two-dimensional heat conduction process; 2) Except for the outermost cable, the distribution between other cables is basically the same The middle section of the cable is symmetrical, and it can be regarded as a periodic structure model; 3) the materials of each layer are in close contact, regardless of the contact thermal resistance; 4) the materials of each layer are homogeneous and constant. According to the simplified analysis, the heating cable melts snow and ice the governing equation of the internal temperature field is

\[
\frac{\partial \theta}{\partial t} = \frac{\lambda}{pc} \left( \frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} \right) + \frac{q_v}{pc} \tag{1}
\]

In the formula, \( q_v \) is the heat source heating site per unit volume and time, that is, the intensity of the internal heat source; \( \lambda \) is the thermal conductivity of the material; \( \rho \) is the material density; \( c \) is the mass heat capacity of the material; \( \theta \) is the temperature of the test piece; \( t \) is the time.
3.3. Boundary conditions
Due to the symmetry of the temperature field, the two planes parallel to the cable laying direction, namely the ac plane and the bd plane (see Figure 2), can be approximately regarded as adiabatic plane.

![Figure 2. Calculation model of heating cable](image)

\[ \frac{\partial \theta}{\partial x} = 0 \]  
(2)

The heating cable works at a constant power, that is, the heating power (line power) of its unit length is known, and it is converted into the heat flux of the surface

\[ q_L = q_0 \]  
(3)

In the formula, \( q_L \) is the heating power per unit length of the cable; \( q_0 \) is the heat flux calculated from the heating power of the cable. The road surface is the ab surface (see Figure 2), which has both the convective heat transfer between the road surface and air, and the road Radiation heat transfer between surface and air and surrounding objects

\[ h_c \frac{\partial \theta}{\partial y} = h_\alpha (\theta - \theta_a) \]  
(4)

In the formula, \( h_c \) is the comprehensive heat transfer coefficient of the road surface; \( \theta_a \) is the outdoor air temperature. In the analysis process, the heat required for snow melting includes: the heat required to increase the temperature of the snow; convection heat exchange and sky radiation heat exchange the heat taken away by the snowmelt. The energy of the snowmelt mainly comes from the heat release of the heating cable, in addition to the solar radiant heat can also provide part of the energy. According to the literature [1] on the thermal method of snow melting, the temperature of the sky and the air temperature during snowfall Consistent temperature

\[ h_c = h_f + \omega \frac{v_c \rho_c c H_{ce} - \alpha d}{\theta - \theta_a} \]  
(5)
Where \( h_f \) is the convective heat transfer coefficient of the road surface; \( c_s \) is the mass heat capacity of snow; \( c_w \) is the mass heat capacity of water; \( \rho_w \) is the density of water; \( H_{fs} \) is the latent heat of melting snow; \( \varepsilon \) is the blackness of the road surface; \( \alpha \) is the surface solar radiation Endothermic rate.

In theory, this problem belongs to the unsteady heat conduction of semi-infinite objects. The deeper the soil is from the upper surface, the smaller the temperature change, and the temperature gradient to infinite depth tends to 0. In the calculation model, the local season is the largest the thickness of the frozen soil is as deep as the CD surface (see Figure 2). The laying depth of the heating cable is very close to the upper surface, and the convective heat dissipation and radiation heat sting due to wind and temperature differences are relatively large, while the heating cable has a lower The Gray gravel and the soil only conduct heat, and the temperature change is very slow close to the cd surface, which can be considered to be adiabatic here. That is

\[
\frac{\partial \theta}{\partial y} = 0 \quad (6)
\]

3.4. Solution process
The heating process of the heating cable snow melting and ice melting system is divided into two stages: the first stage is the preheating stage. During this time, the heating cable releases heat, the structural layer absorbs heat, and the temperature in the road structure layer and the upper surface rises rapidly; The second stage is that the heat emitted by the heating cable makes up for the heat loss of the road structure layer and the upper surface, making the system temperature field stable. But in practice, the temperature is constantly changing. At this stage, when the outdoor weather conditions change, the heating cable the snow and ice melting system quickly reached new stability, and the temperature field of the system can be calculated according to the weather conditions at that time.

4. Energy consumption analysis of heating cable ground in residence
The working principle of the heating cable ground radiant heating system is to lay the special heating cable in the cushion under the floor of the room. When the heating cable is energized, its working temperature is 40 °C ~ 60 °C. A new type of heating system in which electric energy is converted into heat energy by using a heating cable as a heating element, and the heat is transferred to the room to achieve the purpose of heating. In the heating system, the conversion of electrical energy into thermal energy has a thermal efficiency of more than 99%, of which radiant heat exchange accounts for more than 60% of the total heat exchange.

Energy saving is mainly achieved by the envelope structure, so the boiler operation efficiency and pipe network transmission efficiency are still unchanged according to the JGJ26 representative 1995 standard (i.e. boiler operation efficiency 0.68, outdoor pipe network transmission efficiency 0.9). According to the calculation formula of heating coal consumption index:

\[
qc = 2AZqH / HCN_\eta_1 \eta_2 \quad (7)
\]

In the formula, \( qc \) stands for heating coal consumption index, taking 8.82kg / m2 standard coal: \( Z \) stands for heating period days, \( qH \) stands for building heat consumption index, \( W / m^2 \); \( HC \) stands for standard coal heating value, taking 8.14X103 (W · h) / kg; \( \eta_1 \) represents the outdoor pipe network transmission efficiency, which is 0.90; \( \eta_2 \) represents the boiler operating efficiency, which is 0.68.
4.1. Control energy saving function (constant temperature control and regulation control)
If the house adopts regulation control and economic operation, there is a warm way, that is, the room temperature is kept at 5 °C during working hours, and the room temperature is kept at 18 °C at other times. Compared with the all-day heating mode, theoretically, the annual energy saving can be 16%, but the actual savings is 18.7 yuan / m² year × 16% = 2.99 yuan / m².

4.2. Radiant floor heating
According to the relevant regulations, when the ground radiant heating system is used for design calculation, if the indoor temperature is reduced by 2 °C, 7% of the cost can be saved. The actual operating cost savings are: 18.7 × 0.07 = 1.31 yuan / m² / heating season. From the above analysis, we can see that in theory, the ideal operating cost of a building that meets the three-step energy saving requirement in Beijing is: 18.7-2.99-1.31=14.4 yuan / m² / heating season.

5. Wireless radio frequency technology application design plan

5.1. Radio frequency overview
RFID (Radio Frequency Identification) technology, also known as electronic tag or wireless tag, is a non-contact automatic identification technology using wireless communication. RFID is a perfect combination of wireless communication and automatic identification technology. One of the promising IT technologies. The system consists of a wireless electronic tag (radio frequency tag) and a reader. The tag has a calibration frequency of 168.9kHz. The electronic tag can store a certain amount of cable device attribute information. It is installed in the cable channel and carries a radio frequency reader with the corresponding frequency on the road surface. Can penetrate the soil or concrete for data and exchange, the reader displays the information stored in the tag, and locates the position of the tag, at the same time can calculate the tag installation depth and other data. The exchange principle of the RF data identification system is shown in Figure 3.

![Figure 3. Schematic diagram of electronic identification system](image)

The cable electronic mark is made by special packaging of the radio frequency chip, which can be laid by embedded binding and fixing according to the customer's custom shape. By reading the channel identification chip through the handheld, you can know the name of the channel, the
beginning and end of the channel, the name change, detailed information of each cable, etc. Once the cable electronic mark is installed on the cable, it can permanently identify the attributes of the cable. You can get all the attributes of the cable by reading the identification chip through the handheld computer. Its characteristics are:

(1) The electronic chip is used as the carrier of the cable attribute information, which has a large capacity and can fully record all the attributes of the cable; (2) The chip is packaged in a special material, which is corrosion-resistant and has a longer life than the cable body; The one-way self-locking structure, once attached to the cable, cannot be disassembled and resists the impact of large external forces; (4) The attribute information of the cable can be written, read and changed through the handheld unit, and responsible research and information can be realized Confidentiality; (5) Cable electronic identification system is to collect all channel electronic identification and cable electronic identification information through database technology to form a ledger system. Specific functions include: collection of channel electronic identification and cable electronic identification data; channels and the generation of cable ledger; channel, cable query, retrieval; channel change research; cable relocation research; responsibility traceability and authorization password generation, etc. The large-capacity radio frequency identification chip is packaged into a cable identification and a channel identification, so that each cable and each channel have an electronic ID card. "Using a portable handheld device, you can write, read, and read the cable attribute information carried by the chip. Changes, automatic updates, collections, etc.

5.2. On-site holographic modelling technology
Underground cable information marking points are ground marking points or underground electronic information markers located near the characteristic points of underground pipelines and their auxiliary facilities for the purpose of mapping underground cables and returning to the site in the future to find underground cables. According to the setting on the ground or underground, it is divided into obvious cable points and hidden cable points. In the process of determining the exploration content, it is necessary to clarify the obvious and concealed cable point setting principles and setting methods, such as cable line plane position, direction, start and end points, buried depth, depth change point, turning arc path, pipeline crossing, road, Rivers, roads and other crossings, T-shaped branch points, two ends of the protective pipe, the position of the middle head, etc.

5.3. Installation of electronic signs
After site investigation and cable verification, the location of the electronic mark is determined at certain intervals according to the path of the cable line and the cable. Install electronic signs at the cable bends, both ends of the cable's buried depth change, the cable middle joints, the connection points on both sides of the cable protection tube, the manhole cover, and T-branch. The detailed attributes of each cable are entered on the label, including line name, voltage level, cable type, construction date, completion date, construction unit, construction personnel, cable length and other information. At the same time, assign codes to each electronic sign, and explain and mark the position of the electronic sign in the construction drawings [5].

6. Case analysis
The model is used to predict the temperature rise of the road surface, and A, B, C, D and E are taken as 5 typical points on the road surface. As shown in Figure 4. due to. The symmetry and periodicity of the system can be used to analyse the temperature rise of the entire system surface through these five typical points.
Figure 4. Schematic diagram of the typical position distribution of the specimen

Figure 5 shows the simulation of the temperature change of typical points on the road surface with time under different outdoor temperatures. When the outdoor temperature is constant, the temperature curve at each point should be a convex curve, as shown in Figure 5 (a), the temperature rise curve calculated when the outdoor temperature is constant at -15 °C, the road surface temperature in the initial period of time. The curve shows an upward trend. The temperature rises faster. With the progress of the heat conduction process, there is heat storage in the structural layer, the temperature rise slows down, the temperature field gradually develops to a stable state, and the temperature curve tends to be flat. However, in practice, the outdoor temperature changes continuously with time, so in reality, the heating curve will change. Figure 5 (b) shows that the temperature of a typical point on the road surface changes with time under the -9-7 °C climate condition. In the simulated situation, the initial temperature of the outdoor temperature was -7 °C and it remained basically unchanged in the first 7h, so the temperature increased rapidly during this period, but after 7h, the outdoor temperature dropped from -7 °C to -9 °C, the rate of temperature increase slows down and tends to be stable. It can be seen that the temperature change at each point is closely related to the outdoor temperature [6].
Figure 5. Prediction results of temperature rise curves at various points under different outdoor air temperature conditions

When using RSSI to analyse the attenuation of radio frequency signals, you must know the A value and the n value. These two values are both empirical values and are related to the specific node hardware and propagation environment. The wireless sensor network node (GAINS) was used to calibrate the A value at different antenna heights as shown in Table 1.

Table 1. A value measured at different antenna heights

| Measuring distance /m | Antenna height /cm | A value /dBm |
|-----------------------|--------------------|--------------|
| 1                     | 75                 | -53.29007285 |
| 1                     | 100                | -53.41571777 |
| 1                     | 125                | -53.31321797 |
| 1                     | 150                | -53.37604043 |

7. Conclusion

In this paper, based on the full study of the operating environment of cable equipment, cable technical specifications and current temperature measurement technology, this paper proposes a comprehensive energy measurement system for wireless RF acquisition terminal cables. Temperature measurement improves the reliability and practicability of the online monitoring system and promotes the development of cable equipment condition detection technology.

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