

# The Research on the Ice Thickness Detection System Based On Capacitance Sensor

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**Abstract.** A transmission line remote monitoring system combined with wireless sensor technology was designed, through the single-chip computer control to complete the system data from the collection to send all aspects of data processing work. The icing monitoring system uses capacitive thickness detection sensors to collect data from multiple capacitance values and send the collected data to the control center processor through the serial port. The processor then processes the data and stores it on the SD card. in. Through the single-chip computer control to complete the system data from collection to send all aspects of data processing. The processor finishes the data transmission and connects with the GPRS communication module through the RS232 serial port. The automatic detection of ice thickness using the difference in resistance characteristics of air and ice, it is a new type of object surface ice coating thickness detection method. The utility model can be applied to real-time continuous automatic monitoring engineering application fields of high-pressure transmission lines and fixed towers, buildings or various equipment surfaces, suspension brackets, forest branches, and the like.

## 1. Introduction

With the rapid development of wireless communication technology and low power consumption embedded computing technology, Wireless Sensor network (WSN) has emerged as a combination of various modern information technologies. The WSN has the characteristics of fast deployment, low cost and strong adaptability. It is widely used in environmental monitoring, disaster prediction and other fields, it is an indispensable key technology in new interactive systems such as the Internet of things and information physical fusion system[1-3]. The high voltage overhead transmission line's safe operation is the key to the reliable transmission of electric energy and the stable operation of the whole network. overhead lines icing situation is usually occurs in areas with complex terrain and harsh environment. Therefore, traditional manual inspection methods cannot be solved(traditional manual inspection methods cannot solve it ). A variety of overhead line icing monitoring system has emerged , at present, the prediction model detection system has been widely applied. However, there are a number of factors affecting the ice formation of transmission lines. The prediction model may produce an obvious deviation, it's not very reliable [4-7] .

## 2. Principle of line icing

Transmission line icing is related to the geography of the wire, if the transmission lines are erected in the mountains, the direction of the mountain range and the slope of the slope will have a great impact



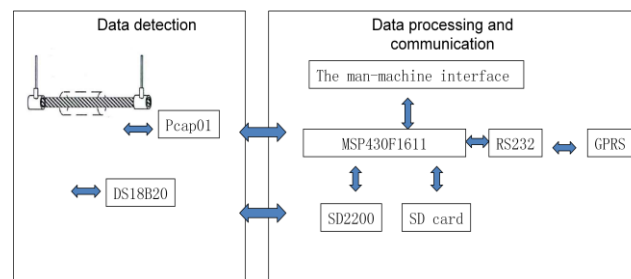
on the icing. In addition, the relative position of transmission lines and water sources will directly affect the thickness of the ice. The common types of ice cover are showed in table 1[8-9].

**Table 1.** The type of ice cover and the formation reason

NO.	type	reason	characteristic
1	glaze	Because the near-earth temperature is low, as the snowflakes fall, they turn into drops of water., the water droplets fall to the surface of the object in the form of cooling water droplets.	The adhesion is very strong and the density is very high
2	Mixed battle	The ambient temperature is below freezing point and the wind is strong.	The adhesion force is stronger, the density is larger, and it's application grows faster
3	Soft rime	The lower clouds in the mountain range have lower temperature and less wind speed.	Weak adhesion, small density, less threat to wire
4	white frost	Moisture in the air comes in contact with objects below the freezing point, and the moisture condenses on the surface.	The cohesive force is very weak, and it is hardly a serious hazard to the conductor
5	snow	The snow in the air is high humidity, and the wind is insufficient.	Wind - driven, plain or low-lying areas are more common.

### 3. Ice monitoring system scheme

The block diagram of icing monitoring system is shown in figure 1:

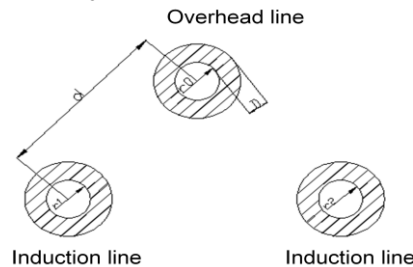


**Figure 1.** Block diagram of ice thickness detection system.

The measuring module of ice monitoring system includes two parts: capacitance measuring circuit and temperature sensor. We used a capacitive sensor that reflects the thickness of the ice coating, an overhead transmission line is used as one of the plates of this capacitor, and the other plate is a parallel induction line erected along the overhead line, therefore, if there is ice covering between the plates, the medium between the plates will change, and the capacitance value of the sensor will change accordingly, moreover, the variation value varies with the thickness of the ice cover. The temperature of the transmission line will increase with the increase of the temperature current. Because the current power line carrier is larger when the temperature increases, and that will affect the measurement results. A temperature compensation circuit is added to the monitoring system to ensure that the temperature of the two plates is consistent. The temperature compensation device detects the temperature difference between the two plates by the temperature sensor installed on the sensor line, and the temperature of the plate is kept in accordance with the control temperature of the heating device. The power module of the monitoring system adopts solar power supply mode to charge the system battery.

### 4. Ice Thickness Detection Algorithm

The structure diagram of ice thickness detection circuit is shown in figure 2, transmission line parallels l to induction line, the cross-sectional area of the two lines is denoted as R1, R2, respectively, the distance between the transmission line and the sensing line is d. Assuming that the thickness of the ice overlay on the two lines is D at a certain moment, the dielectric constant of air is expressed, and the dielectric constant of the ice overlay is  $\epsilon_0$ , The dielectric constant of ice coating is  $\epsilon_1$ .



**Figure 2.** The structure diagram of ice thickness detection circuit

According to Chang Ching, etc [8], The capacitance between two bare wires in the air with a radius of R and a distance of d is shown in Equation 4-1:

$$C = \frac{Q}{U} = \frac{2\pi\epsilon_r}{\ln\left[\frac{d^2 - R_1^2 - R_2^2}{2R_1R_2} + \sqrt{\left(\frac{d^2 - R_1^2 - R_2^2}{2R_1R_2}\right)^2 - 1}\right]} \quad (4-1)$$

## 5. Ice thickness detection sensor coverage model

The ice coverage detection system sensor network probability coverage model is shown in Equation 5-1:

$$P_p(S) = \begin{cases} 1, D(S, P) < R \\ \lambda e^{-a(D-RS)}, D(S, P) \geq R \end{cases} \quad (5-1)$$

The distribution of ice coating directly affects the distribution of wireless sensor networks. The geographical factors in the area are directly related to the distribution of ice coating. For example, ice thickness increases with altitude. Taking into account the impact of terrain and other factors on the coverage of wireless sensor networks, a new variable  $\lambda$  is introduced, and  $0 \leq \lambda \leq 1$ , when the height difference between the target position and the sensor is greater,  $\lambda$  is smaller, and when The greater the change in climate conditions between the target location and the sensor, the smaller the value of  $\lambda$ .

In the formula:

D(s.p) refers to the distance between the sensor and the target location

R: refers to the vertical span of the sensor; a: indicates the sensor's detection capability coefficient

## 6. Ice coating sensor detection system designing

### 6.1. Controller selection

Based on the requirements of low power consumption and data processing capability required for actual projects, the MSP430 processor F1611 from Texas Instruments was selected. As shown in table 2:

**Table 2.** MSP430 I/O ports and function allocation

I/O port	Features
P1	Clock reset

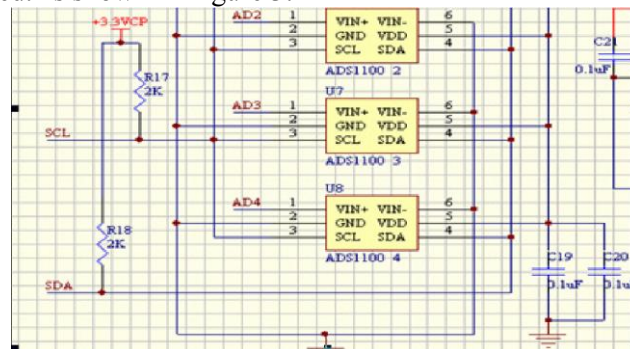
P2	Power module control port
P3	LCD control port
P4	Sensor connection port
P5	Data access port
P6	Alternate port

### 6.2. Temperature sensor selection

According to the requirements of ambient temperature and measurement accuracy of transmission lines, DS18B20 digital temperature sensor was selected as the temperature measurement device, Temperature measurement from minus 55 degrees Celsius to zero over 125 degrees Celsius can be achieved, measurement accuracy can reach 0.5 degrees Celsius, and multi-point networking capability.

### 6.3. A/D conversion module selection

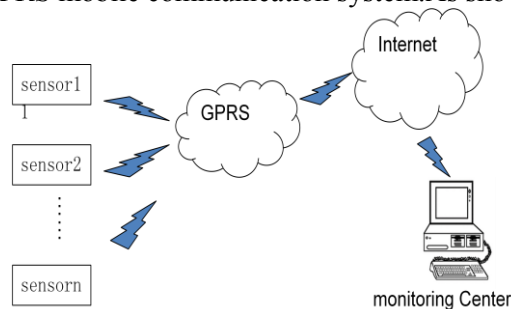
We selected TI's ADS1100, with a 6-pin DIP package, it can sample 8, 16, 32, or 128 samples per second for conversion. On-Chip PGA Provides 8x Gain. it has a high resolution, smaller signal detection can be achieved. As shown in Figure 3:



**Figure3.** ADS1100 single-ended input typical connection circuit

### 6.4. Data transmission module selection

According to the transmission line detection position is mostly away from the detection center characteristics, we selected GPRS mobile communication system. As shown in Figure 4:



**Figure4.** Wireless data network diagram

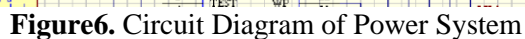
### 6.5. SD card data storage module design

We chose 1-bit SD mode, namely SPI mode. It has independent instructions and data channels, unique transmission format; SCM and SD card interface circuit shown in Figure 5:



### 6.6. System power design

Because the transmission line environment is relatively complicated,,solar panel battery supply side is used in this system.The power supply used is the LM2575-3.3. The circuit is shown in Figure 6:

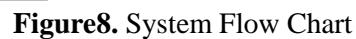
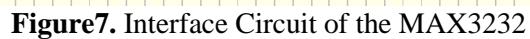


### 6.7. Serial communication module design

We selected MAX3232 and MSP430F1611, interface circuit shown in Figure 7:

### 6.8. The system flow chart

Monitoring system flow chart shown in Figure 8:



## 7. Conclusion

The basic module of the ice-covering monitoring system is a capacitive thickness detection sensor. It can perform data acquisition on multiple capacitance values, send the collected data to the control center processor through the I2C serial port, Then the processor processes the data and stores it in the SD card. MSP430 MCU is the core component of the system, Through the single-chip computer control to complete the system data from the collection to send all aspects of data processing work. Processor SCM completes data transmission through RS232 serial port and GPRS communication module connection.

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