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Expert System of Icing and Anti-icing on Wires in Freezing Rain

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Abstract*-The freezing rain storm of 2008 in south-central China caused much damage to overhead transmission lines, the electrical installations and railway contact conductors. One of the most effective ways is to use the joule heat generated by electric current to carry out Anti-icing. Taking a overhead line as a research object, a mathematical model of icing and anti-icing joule heat in freezing rain was established based on the heat balance equation and a computational program was written in C language. The meteorological parameters such as wind speed, precipitation rate, air temperature, solar radiation and atmospheric pressure were used as the model inputs. Under Labview platform, wind speed , atmospheric pressure and temperature is gathered by a hot-wire anemometer through RS232 serial port and others were obtained from the local meteorological station, and then , transmitted to computers and processed by the decision-making model embedded in Labview by using mixed laguage programming technology. This expert system can provide reliable suggestions for electrical engineers to prevent icing on transmission lines in freezing rain.

Keywords- expert system; icing; anti-icing; wires

I. INTRODUCTION

The overhead electrical transmission lines icing may cause a series of problem such as overloading, non-uniform icing, and wire galloping etc. In countries with cold climates such as Canada, U.S.A and China, glaze and rime ice accretion on power transmission lines is a headache for electrical engineers and scientists[1]. The research on the mechanisms of icing and anti-icing is both a basis of transmission line design and a new objective of the environmental thermophysics study[2].

The electrical heating of conductors by the Joule effect offers a potential method for preventing ice accretion on the conductor surface. The minimum current intensity which prevents from icing on overhead transmission lines is called anti-icing current intensity. The nominal current in overhead transmission lines is increased in such a way that it keeps the conductor surface temperature slightly above the freezing temperature. This method should be adopted a certain time before and during the ice accretion.

Makkenon and Jones put forward the heat balance equation of icing on wires [3-7]. Zsolt make experiments of ice prevention on well-controlled wind tunnel and a total of 80 tests were carried out[7-8]. In this work, the prediction of ice accretion in freezing rain is made based on the meteorological parameters such as air temperature, , precipitation, wind speed, and then, heat balance method is adopted in the calculation of anti-icing current Joule heat in freezing rain. Under Labview environment, data acquisition board is used to collect data from various sensors and then sent to expert decision-making system in which ice accretion prediction and anti-icing current Joule heat model are incorporated.

II ICING AND ANTI-ICING JOULE HEAT

A. Icing Models

Jones's report[3] describes two freezing-rain models developed to use the historical hourly weather data and called a detailed heat-balance model that determines the amount of the impinging rain that freezes either directly to a structure or as icicles. Fig.1 shows the calculation flow chart of the heat balance method.

The calculation precedure is written in C++ and complied to dll (dynamic link library) called by Labview as decision-making model.

B. Anti-icing Joule heat in freezing rain

The anti-icing Joule heat equation P can be get from the heat balance equation :

$$P + Q_k + Q_v = Q_c + Q_w + Q_e$$

where

$$w(g/m^2 s) = \left[\left(\frac{P\rho_0}{3.6}\right)^2 + (WV)^2 \right]^{0.5}$$

, the flux of precipitation w is the vector sum of the vertical and horizontal water fluxes, $P\rho o$ and WV.

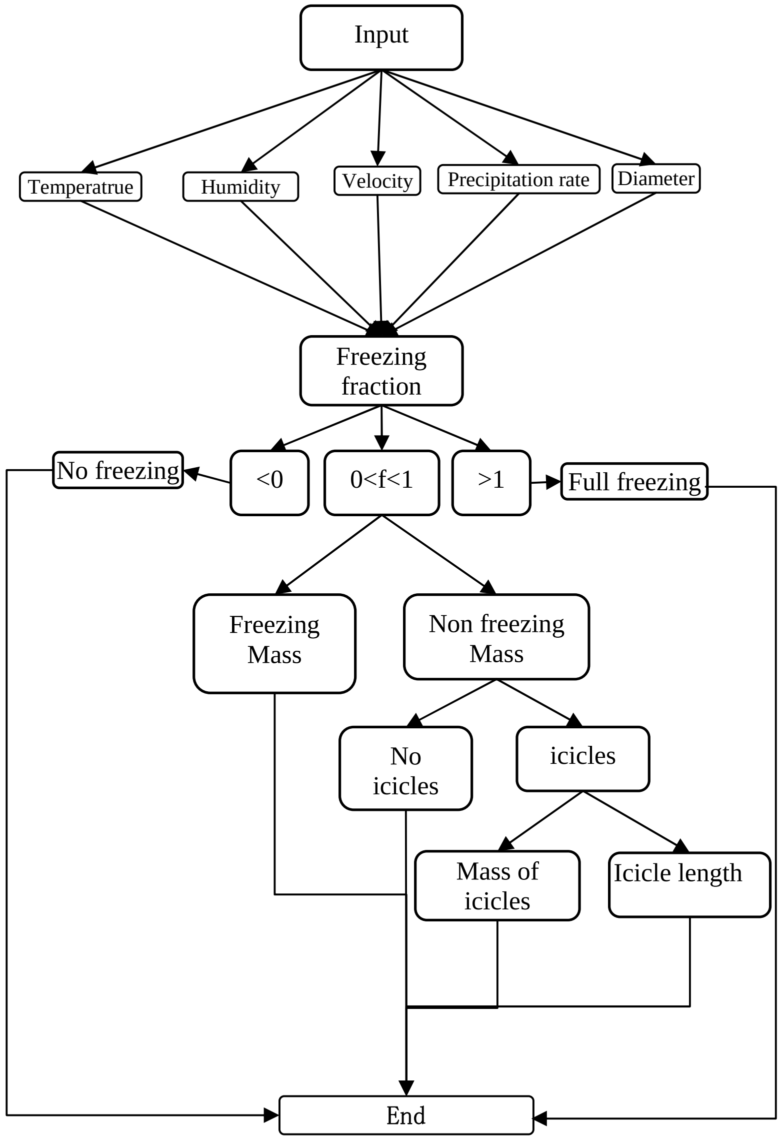

Figure 1: Calculation flow chart of the heat balance method

$Q_c = -h\pi(0-T)D$, convective cooling flux

$Q_w = -c_w w(0-T)D$, cooling flux required to warm the incoming water to 0°C

$Q_e = -\pi D\frac{0.62hl_e(e_s-e_a)}{2c_p p_a}$,evaporative cooling flux

$Q_v = 10^{-3}\pi hr_v V^2 D/(2c_p)$, viscous heating flux

$Q_k = 10^{-3} wD\left\{V^2 + \left[P\rho_0/(3.6W)\right]^2\right\}/2$, heat flux from droplet kinetic energy

$$P = h\pi(0-T)D + c_w w(0-T)D + \pi D\frac{0.62hl_e(e_s-e_a)}{2c_p p_a} - 10^{-3} wD\left\{V^2 + \left[P\rho_0/(3.6W)\right]^2\right\}/2 - 10^{-3}\pi hr_v V^2 D/(2c_p)$$

III. EXPERT SYSTEM

The experts system includes the data acquisition, experts decision-making system and data management. The structure is shown in Fig.2

In data acquisition module[11-12], the temperature, humidity, direction and velocity of free stream can be collected directly from hot-wire anemometer, Signals are achieved by various sensors, and then amplified, filtered and A/D converted. The final signals are acquired from data acquisition card to a computer for further analysis. The DAQ (PCI-4472) card of NI (American National Instruments) is used.

Based on method mentioned above, the experts decision-making system can estimate icing according to the meteorological parameters such as air temperature, Precipitation and wind speed obtained by corresponding sensors. Another other main function of the system is to calculate the anti-icing Joule heat. The above mentioned calculation program is incorporated in the experts system. The data management is responsible for data save and reader.

The freezing fraction and the icicles mass MI can be used to determine whether icing or appearing icicles . if icing or icicles happens, colour change of two indicator light will display on the front panel. The total ice mass changes over time will be drawn on waveform graph . The main interface of the program is as follows:

The entire program is event-driven(Fig.3). Clicking the start , data collection begins. Clicking the stop button will pause acquisition, if we want to continue acquisition click start button again. The collected temperature and wind speed in real-time will be two waveforms chart.

Icing calculation module (Fig.4) provides manual input meteorological data and calculated function. In the corresponding textbox input a set of data, and then click ok button, the background calculation program will take this group data as input to get the ice mass and ice sleeve diameter.

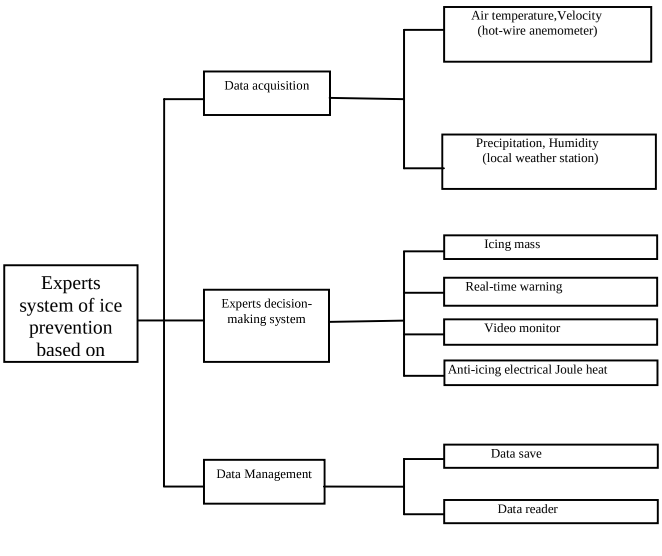

Figure 2: The structure of experts system

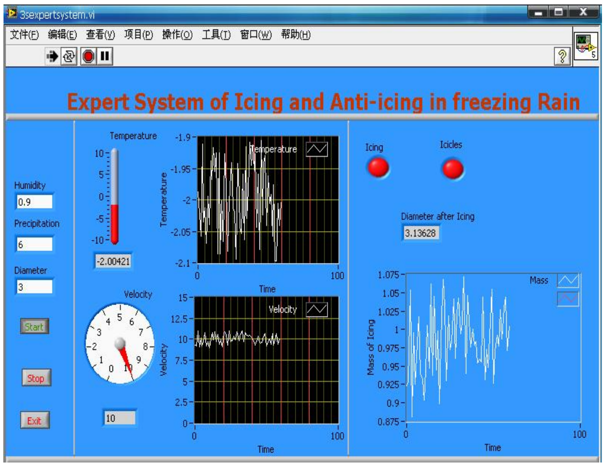

Figure 3: Main Interface of the system

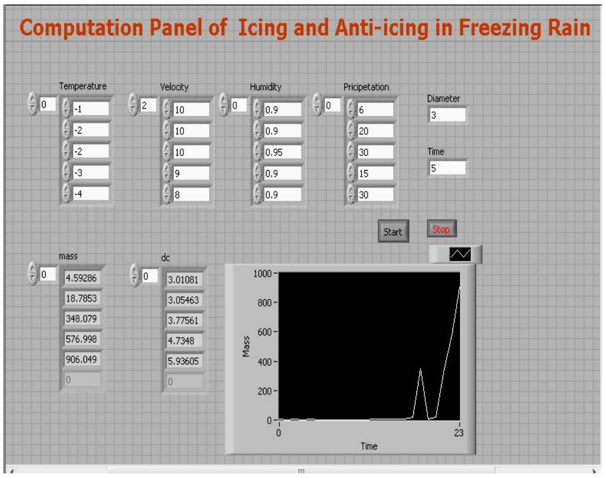

Figure 4: Icing calculation module

IV Conclusion

1) The expert system can estimate ice mass in freezing rain according to the meteorological parameters.

2) The system can calculate the Joule heat required to prevent ice accretion in freezing rain based on numerical technology.

3) The system can also be used for the electrical railway contact lines to give a decision-making for electrical engineer

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