Control Software for Surface Ice and Snow Detecting Device

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Abstract

The paper discusses the principles of designing and developing control software used in the system for detecting ice and snow buildup on controlled surface, with the principles for identifying the best-suited method of detecting. The paper also describes basic principles underlying the development of ice and snow buildup detection systems used on railway switches which results in improved sensitivity and precision of the data collected and processed allowing for reduction of electric power consumption and improved reliability and longer life of detection devices.

Introduction

Higher speeds and heavier traffic coupled with demands for lower costs require new solutions to improve efficiency of railway equipment including electric heating applications. Most essential among the properties of equipment required are longer useful life and lower maintenance and repair costs.

In their turn, more demanding requirements make it necessary to develop innovative technologies providing solutions which will produce more energy-efficient, reliable, ecology-friendly systems with higher-precision measuring of physical values and, hence, more reliable and exact data for decision-making in the process of control.

Principles underlying electric heating system operation, control units and other system components are to ensure electric power saving, high reliability during the useful life of heating equipment, less time and money consuming installation, easier and less costly maintenance, quick and easy assessment of the equipment condition.

Modern railways use excessively thermal equipment and systems to prevent faulty operation of railway switches and other mechanical devices caused by pressed snow and ice buildup – which is often the case in the cold seasons of the year.

Currently available wide range of equipment used to prevent faulty operation caused by ice and show buildup can be classified into types and classes according to the principles of their operation: mechanical, pneumatic, thermal and combined devices and systems. Most widely applied – of all currently available thermal systems – are electrical heating systems.

Currently the system which finds the widest application in the railway industry for heating switches is SEIT-04M. It consists of TEHs mounted on frame rails, outdoor air temperature sensor, switch, precipitation sensor, comparing element (in which the outdoor air temperature sensor is connected to the second input of the comparing element) with only one rail temperature sensor mounted on frame rail and connected to the first input of the comparing element [Wol16, Bro12, Sel19 & Bar16].

Given all the advantages of the analogue the following causes can be identified which prevent high-efficiency operation of the device (according to the present application):

- No information is provided of the type (based on 'input signal comparison') of the electronic data processing (EDP) device used, and no explanation and description are given for 'specific algorithm' and 'specific software'. There are many reasons to suggest the EDP device organization as that of an automatic controller of poorer quality and less possibilities compared to modern EDP devices – logic-based EDPs performing logic operations/gates with the input signals processed according to the algebra of logic principles to produce output signals relevant for the effective function values.

- No indication is given as to possibility or impossibility to quickly change the algorithm and software given or involvement in operation of the control personnel (including operators) of various levels either by changing algorithm or by manual two- or three-level duplication with priority ranging. This condition has a negative effect on technical and logistic properties of the prototype when the system is implemented extensively thus causing higher probability of faults and resulting accidents and emergencies.
- Such application makes insufficient use of current digital technologies and automated workstations.

The task to be solved by the present application is improved technical and operational properties, economic efficiency and wider range of technical and operational options for electric heating systems installed on either railway switches or other elements of railway infrastructure. The achievement of the above properties is ensured by higher reliability, reduced energy consumption and options of both local and multilevel remote control.

One of the basic requirements of precipitation-detecting system on the controlled surface is regular updates of ice or snow presence/absence measurements on the precipitation sensor surface. After the request by EDP device the sensor elements transfer the data required.

EDP device summarizes the data (digitized signals) from the system data sources. The data collected are archived, and the archives and the decisive rule set ('precipitation-present' feature developed) are used by the system to decide on the presence or absence of precipitation. The system assesses condition of the sensor surface as 'precipitation present' or 'precipitation absent' applying the criterion based on the phenomenon of temporary (or partial) stabilization of the sensor surface temperature at the level of shift between phases [Kho19].

Signal values accumulated in the current cycle are stored in the EDP device RAM and are transferred via the serial communication channel to external flash memory device which stores the data together with the condition properties produced by the precipitation sensor and the current time as a file. The data received can be printed out by sending them to a special printer device or varied formats of the data output.

As the above description shows, the first block of the system collects the data, the second block summarizes the data obtained from the sensor elements (sources), the third block performs data archiving and, finally, the fourth block develops the 'precipitation present' or 'precipitation absent' feature. Fig. 1 shows a possible system architecture design based on the description given above. It presents a multilevel design which gives all stages of data processing by the system, i.e. data collection, summarization, archiving, precipitation-relevant feature development. Such architecture design can be applied for the system described as each stage based on the data processed at the previous stage.

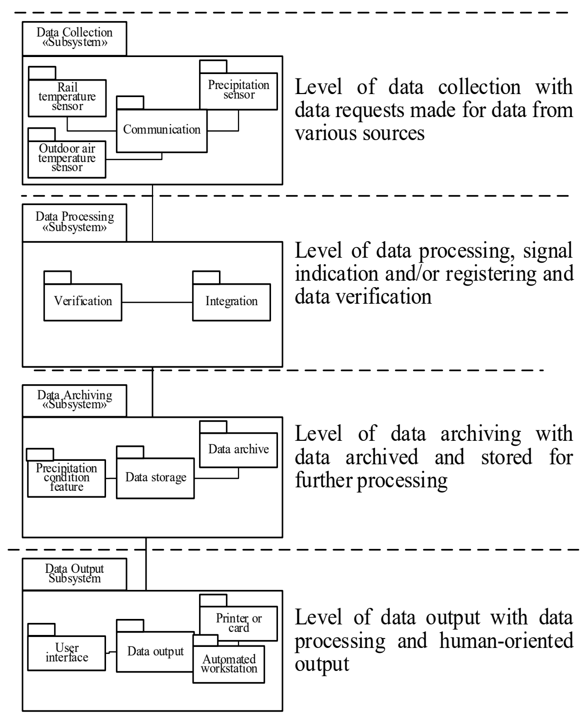


Figure 1: Multilevel EDP device system architecture design

Figure 1 shows all levels of the system with detailed structures of subsystems. The elements of the subsystems presented are of abstract character and are implied by the information on the system described. The names of the levels are given within boxes which, in UML notation, refers to subsystems (a set of objects and other systems). Such representation allows to demonstrate each level as consisting of multiple elements[Kho19].

System Environment and Models

The process of system designing implies revealing interaction and connections of the software being developed and the environment. Interaction and connections revealed allow for solutions which provide for both the functionality required and the system design ensuring efficient interaction between the system and its environment.

The UML notation-based model of system environment can be expanded into a set of subsystems. When presented in such a way, the ice and snow buildup detecting system environment is shown as existing within the data collection subsystem. Other subsystems which make up the system of the ice and snow buildup detecting on controlled surface are also given there.

The ice and snow melting thermal system interacts with external to the system objects during the start and the stop stages, during compiling reports (at the stage of 'precipitation present' or 'precipitation absent' feature development) using the data collected and during the stage of testing and calibration of meteorological instruments (Fig.2).

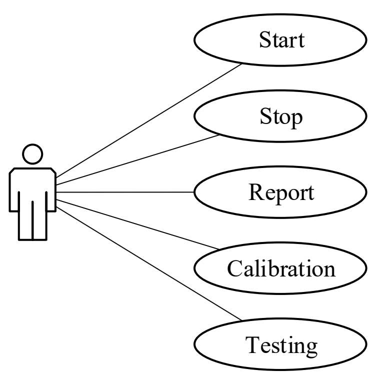


Figure 2: Options of ice and snow melting thermal system

System	Communication
Possible application	'Precipitation present' feature development
Elements	Data collection system, ice and snow melting thermal system, comparing element
Data	On terminating the measurement cycle the comparing element forms a report with the data of sensor measurements within a given period collected by the data collection system. The report contains the initial temperature on the sensor plate surface timed from the heating element switch-on to the temperature value above the threshold value of solid-to-liquid phase (0°C)
Input signals	Sensor is connected to the hardware with units for controlling, measuring, data processing, signal indicating and/or registering and data transfer, which, coupled with the sensor, form the device for detecting ice and snow buildup on the controlled surface
Feedback	The resulting data are transferred to system of the ice and snow melting-related data
Comment	The request is made for report on the criterion set based on application of the surface temperature temporary stabilization phenomenon with frequency of reporting varying with station and time. In relation to a given sensor plate the conclusion of either 'precipitation present' or 'precipitation absent' is drawn based on temporary stabilization phenomenon criterion.

Development of specific algorithm for control and data collecting and processing system for detecting snow or ice buildup on the controlled surface can be shown as block-chart. Block-chart allows algorithm design visualized thus allowing for algorithm operation to be analyzed and for logic errors in the algorithm implementation to be detected. A typical block-chart is shown in Fig.3 [Ada17, Bey05 & Smo08].

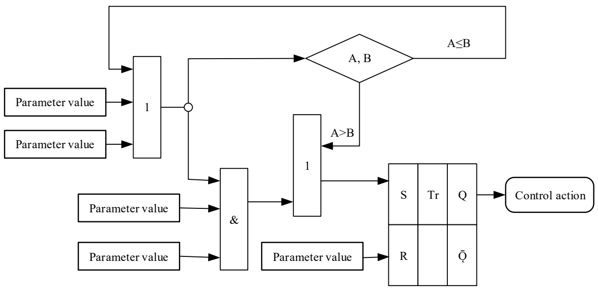


Figure 3: Typical algorithm block-chart: 1 – logic gate OR; & – logic gate AND; A, B – logic gate of comparison; Tr – logic gate RS trigger

Arrows in the block-chart indicate the order of logic operations depending on the chart logic gates parameter values and output signals at the present time.

The typical algorithm block-chart produced, the next stage is to design the structure of control and data collecting and processing system which will provide for the control algorithms implementation. In a generalized form the control and data collecting and processing system for detecting snow or ice buildup on the controlled surface can be presented as shown in Fig.4.

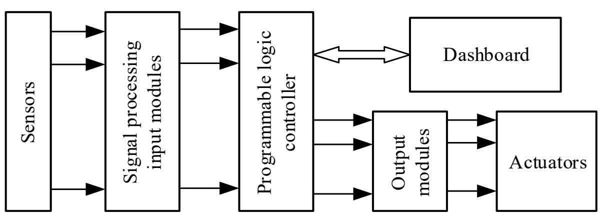


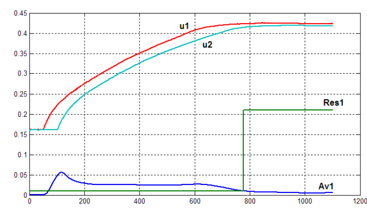
Figure 4: Typical design of control and data collecting and processing system for detecting snow or ice buildup on the controlled surface

Control Software Development

Listing 1. Interface of snow or ice buildup detecting system

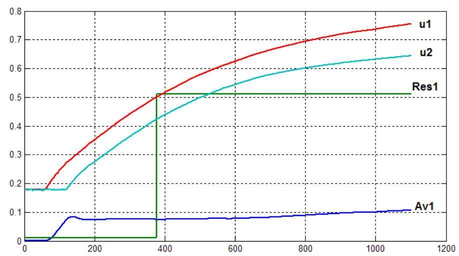
```
close all
clear all

% u1, u2, u5, u6 – test data.

fid=fopen('data_1\1_1.txt'); u2=fscanf(fid,'%e',inf); fclose (fid);
fid=fopen('data_1\1_2.txt'); u1=fscanf(fid,'%e',inf); fclose (fid);

fid=fopen('data_3\1_1.txt'); u6=fscanf(fid,'%e',inf); fclose (fid);
fid=fopen('data_3\1_2.txt'); u5=fscanf(fid,'%e',inf); fclose (fid);

Delay=50;  % Delay of 2nd heating element.
R1=0.01;   % 'Precipitation present' threshold value.
T1=0.5;    % 'Precipitation absent' threshold value.
N1=length(u1);
N3=length(u5);
```

```
N=1100; % Lengths of data array (test of 25_04_2019)
NW=30; % Sliding window length.
Ns=120; % Time of 2nd heating element switch-on.
i=0;
k=1:NW; dif(k)=0;              % Data array shown in window.
k=1:N; Av1(k)=0; Av2(k)=0;    % Median array shown in window.
Res1(k)=0;
sum=0;
while i<N
    sum=sum-dif(NW);
    for k=1:NW-1
        dif(NW-k+1)=dif(NW-k);
    end
    i=i+1;

    ch1=u1(i);
    ch2=u2(i);
    dif(1)=ch1-ch2;
    sum=sum+dif(1);
    Av1(i)=sum/NW;
    if i>Ns && (ch1 > T1 || ch2 > T1) % Decisive rule (precipitation
present feature development)
        Res1(i)=0.5;
    else
        if  i>Ns && Av1(i)<R1
        Res1(i)=0.2;
        end
    end
end
k=1:N;
figure
plot(k,Av1(k),k,Res1(k)+0.01,k,u1(k),k,u2(k))
```



Model operation diagram for 'precipitation present' condition

```
i=0;
k=1:NW; dif(k)=0;              % Data array shown in window.
k=1:N; Av1(k)=0; Av2(k)=0;    % Median array shown in window.
Res1(k)=0;
sum=0;

while i<N
    for k=1:NW-1
        dif(NW-k+1)=dif(NW-k);
    end
    i=i+1;
    sum=sum-dif(NW);
    ch1=u5(i);
    ch2=u6(i);
    dif(1)=ch1-ch2;
    sum=sum+dif(1);
    Av1(i)=sum/NW;

    if i>Ns && (ch1 > T1 || ch2 > T1)  % Decisive rule (precipitation
present feature development
        Res1(i)=0.5;
    else
        if  i>Ns && Av1(i)<R1
        Res1(i)=0.2;
        end
    end

end

k=1:N;
figure
plot(k,Av1(k),k,Res1(k)+0.01,k,u5(k),k,u6(k))
```



Model operation diagram for ‘precipitation absent’ condition

Conclusion

The operation of the device is as follows. Signals from the outputs of the rail temperature sensor, outdoor temperature sensor and precipitation sensor are continuously fed to the inputs of the electronic data processing unit with special software. In the electronic data processing unit with special software, the signals are compared according to a certain algorithm, then the signal from the electronic data processing unit with special software enters the first and second stepless voltage control units, which are included in the secondary windings of the first and second single-phase transformers of the power supply units and transmits voltage to flat oval electric heaters. Thus, the required heating temperature of the frame rails is maintained depending on the air temperature and ambient humidity. The inventive device for cleaning the turnout of snow and ice by electrical heating can reduce energy consumption by up to 60% compared with existing systems, and is also intended to prevent icing and removal of ice and snow in the area of wits and frame rails, cores of crossings of turnouts at stations, parks, slides in order to ensure uninterrupted movement of trains during snowfalls and blizzards. The device provides continuous operation of turnouts in the winter, regardless of precipitation.

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