Novel cost-effective remote ice detection system allows extensive deployment

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Abstract

Remote ice detection systems for black ice alerts and snow counter measure control using infrared based devices have until now been prohibitively costly and extensive deployment has been prevented. This novel ice detection system has properties equal to or exceeding those of older systems, while the innovative design reduces the cost to levels allowing widespread use or use with new applications that until now have not been financially justifiable.

The ice detection system resolves six distinct surface states, from dry surface to wet ice, with corresponding friction levels. The system may also present ice and water layer thickness, which may be useful for aquaplaning alerts or for controlling salt dispensing on icy roads. Remote detection allows mounting of ice detectors at a distance from the road or, alternatively, for ice detection at surfaces that are difficult to access, or for ice detection on moving objects.

Localized ice detection is of particular value at hazardous areas being particularly prone to icing, such as bridges. It is of also of particular value in areas with elderly or children, like entrances to homes for the elderly or kindergartens.

1. Introduction

Systems for remote ice detection based on infrared spectroscopy have been used for at least half a century. These were initially used only for very demanding, typically scientific, applications such as detection of ice in space and later studies of the polar ice caps using satellites. These systems were exceptionally expensive.

Silicon based electronics has been evolving very rapidly since the seventies, allowing more and more demanding applications at ever lower costs. With the evolution of silicon based electronics, software development and software based applications has also increased dramatically. No corresponding reduction in cost levels that allows an increase in complexity has occurred for optical systems. This has until now prevented optical systems, such as remote ice detection systems from being produced at cost levels that allow widespread use.

Silicon based electro-optical detectors and light sources are inexpensive and these are used for generation and detection of light with a wavelength shorter than 1000 nm. Remote ice detection systems do unfortunately use the near infrared wavelength range extending from 1000 nm to 2000 nm, so silicon cannot be used. For such applications, InGaAs based electro-optical devices such as lasers and photodiodes are used. The cost of InGaAs based electro optical devices was initially expected to decrease to a level corresponding to silicon, but this has not been the case. Spectroscopic systems, such as remote ice detectors, based on InGaAs photo detector arrays or InGaAs lasers therefore remain expensive.

Sensice's ice detectors are based on a novel and patented design that circumvents much of the difficulties associated with previous spectroscopic systems. This allows Sensice's ice detectors to be produced at cost levels that make widespread use possible. It further allows applications that previously have not been financially justifiable, and this paper will give an overview of such applications and the benefits of extensive use of ice detectors.

2. Applications of ice detectors

Ice detectors are useful for a range of applications, and these may be subdivided according to geographically/topologically related aspects of applicability and aspects related to use. These will be detailed below

2.1 Geographical and topological distribution of applicability of ice detectors

Detectors for remote detection of ice do have specialized industrial applications which are unrelated to the normally occurring outdoor temperatures and precipitation, but this paper will focus on applications related to icing affecting vehicles and pedestrians.

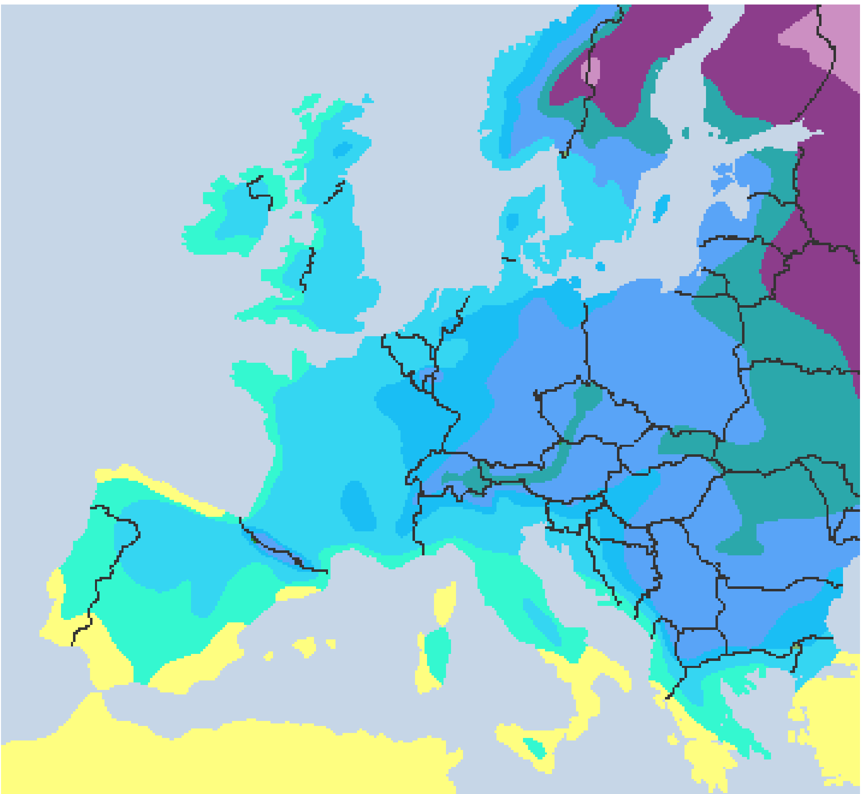

Figure 1. Average annual minimum temperatures. Only light yellow signifies above freezing

Accidents related to icing of roads occur throughout any geographical region where the average annual minimum temperature is below 0°C. As the map over Europe in fig. 1 indicates, almost all of Europe falls within this criterion.

Sensice's ice detectors are able to identify several different kinds of ice and/or water. These are: clear dry ice, clear wet ice, snow, sleet, clear water and turbid water. These have different degrees of applicability through the season. Wet clear ice and dry clear ice are, when appearing on roads, often referred to as black ice. Black ice is the form of ice that is most difficult to detect with the human eye, and it has a very low degree of friction. Sensice's ice detectors are in particular used for remote detection of black ice. Black ice occurs typically when temperatures fluctuate around zero degrees centigrade. These temperature circumstances appear during large parts of the winter season throughout Western Europe, while in northern and Eastern Europe the risk of black ice is at its highest late autumn and early spring.

Table 1. Traffic accidents in Sweden[1] 1995-1999:

At snowy or icy road surface conditions, total	37828
During black ice conditions	15589
Accidents related to aquaplaning	572

Identifying snow and sleet may appear less important than identifying black ice, but its importance lies in it being able to tell invisible, very slippery black ice from clearly visible, much less slippery forms of ice. Sensice's ice detectors are thus able to emit black ice alerts only when this truly is the case.

Temperatures may fluctuate rapidly around zero degrees centigrade, while also relative humidity and precipitation fluctuates rapidly over very limited distances in mountainous regions. Mountainous regions are distributed all over Europe and road and railway traffic has to pass these regions in large volumes. Temperature differences between the east facing hill slope and the west facing slope of one and the same hill may very well be sufficient to have dry roads on one side with black ice on the other. Changes in altitude that are traversed by a vehicle in minutes may correspond to roads changing from dry through wet to icy. Displays at road tunnel entrances and exits are often available, and adding the functionality of Sensice' black ice alerts will add to the usefulness of such information systems. Also, deploying ice detectors at regular intervals along roads that extends with a rapidly varying altitude is now feasible.

2.2 New applications of ice detectors

Cost levels have until the release of Sensice's ice detectors prevented use of ice detectors with traffic related applications other than the most pressing and cost insensitive ones.

Table 2. Present applications using ice detectors

Ice detection on bridge supports, controlling heaters for preventing icicles falling onto paving

Table 3. New applications made possible

Ice detection of the road surface on bridges
Ice detection at tunnel entrances and exits in mountainous regions
Ice detection at regular altitude intervals on roads in mountainous regions
Ice detection at regular intervals on roads in regions with a flat topology

Ice detection at underpasses
Ice detection at roads near kindergartens or homes for the elderly
Ice detection for pedestrians at entrances to hospitals and homes for the elderly
Ice detection for pedestrians at entrances to railway stations, airports, hotels
Ice detection on train rails
Detection of organic matter on train rails, such as leaves
Ice or snow layer thickness measurements for controlling road salt application
Water layer thickness measurements for alerting drivers of risk of aquaplaning
Centralized distribution of information from a set of ice detectors over an extended area
Automated transmission using ia. SMS of alerts to drivers travelling along a particular route

2.2.1 New applications directed towards pedestrians

Often, attempts to make travellers safe in a traffic situation has been directed towards aiding drivers of motorized vehicles such that the risk of accidents involving pedestrians is decreased. Obviously, it is of particular interest to alert drivers to the presence of black ice near places where children, elderly pedestrians and people with disabilities cross roads.

Black ice may however cause accidents to pedestrians without involving vehicles. Such accidents often involve the elderly or disabled; what however is not quite so obvious is that long-distance travellers are a vulnerable group. While locals are well aware of the risk of slippery pavements, long-distance travellers exiting a train, an airport or a hotel in a foreign area may be taken by surprise.

2.2.2 Information collection and distribution of road surface state information

Detection of ice at particularly exposed or sensitive places is of little value to anyone but drivers at the place in question, and is probably best presented directly to the drivers with displays. If a sufficient number of reasonably evenly distributed ice detectors is available, such that general information on road surface states may be deduced, it would be advantageous to collect this in real time and make this publicly accessible, for example using a web site. Information regarding the distribution of black ice on roads may also be actively transmitted to travellers in the risk zone or travelling towards it.

2.2.3 Other new uses of ice detection

Ice sheet build-up on rails has a severe effect on trains and, although it may be of limited value to deploy ice detectors for this purpose alone, Sensice's ice detectors are also able to detect turbid water, such as leaves or other organic matter on rails. In certain regions, leaves on train rails cause train traffic delays during the autumn.

Sand and salt is distributed on roads to melt ice and prevent icing. Typically, an unnecessarily large amount of salt is selected such that it is at least sufficient to melt an assumed ice layer thickness. Using actual ice layer thickness measurements, salt dosage may be better controlled, minimizing excess brine run-off from roads.

3. References

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