Test Site data on icing monitors and conductor ice loads

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***Abstract*— EA Technology has a severe weather test site at Deadwater Fell on the Scotland/England border in the UK. This site is described in another paper at this workshop. As part of the COST727 programme, the site has been used to test icemeters and validate icing models. A wet snow model has also been validated on a real wet snow blizzard that occurred in the central England area in 1990 and this is described in another paper at this workshop. Three instruments were identified as likely to accurately monitor icing data: Combi-Tech IceMonitor; Goodrich/Campbell/Rosemount ice monitor; HoloOptics Icing Rate sensor. The PMS icemeter from the Czech Republic was also tested. All the manufacturers agreed to loan their instruments to the COST sites free of charge. The Combi-Tech and PMS instruments were tested in the 2007/08 winter and an upgraded Combi-Tech, Campbell and HoloOptics monitored during the 2008/09 winter. The paper describes the installation of the instruments and their comparative performance. Icing load data on various conductors is given and related to output from the various ice monitors.**

I. BACKGROUND

EA Technology has operated several severe weather test sites throughout the UK since 1988 to encompass a full range of weather conditions: gales, pollution, wet and dry snow, hard and soft rime ice and glaze icing (freezing rain). This paper looks at work carried out at the Deadwater Fell site on the English/Scottish border connected with the COST727 programme. The site itself is fully described elsewhere at this Workshop[1] as is its use with WRF modelling to validate a wet snow model [4].This paper looks at four icemeters and how their output compared with that of the on-site instrumentation and also the ice loads measured on conductors on the 200m test span.

II. THE DEADWATER FELL SITE

The site is fully described in another paper at this workshop [1]. It consists of a 200m test span which currently has up to seven conductors strung. Each conductor is fitted with a load cell to monitor the tension and a video camera to view the ice load. The site is equipped with meteorological instruments fully described in another paper at this Workshop [3]. The span is situated at 590m land height at the top of an isolated hill on the English/Scottish border and the line is orientated North-South between wood H-poles. The Southern H-pole has a platform attached (Figure 2.1) which is used for access to the load cells, vibration monitors and turnbuckles and is also used for mounting the icemeters.

Fig. 2.1 The platform at the southern end of the test span.

III. THE ICEMETERS

A. General

The four icemeters were tested over a two year period over the 2007/08 and 2008/09 winters. Most of the accretion was rime ice with some wet snow periods. No glaze icing was recorded over the test period. Glaze icing is relatively rare in the UK. Rime ice is common but the heaviest accreted loads at land heights up to 600m is generally wet snow. Over the two year period there were around 40 snow/ice incidents (classed as causing tension increases of >10% on the conductors).

B. Combi-Tech IceMonitor

The IceMonitor was originally developed for the use in a power line surveillance system installed in Norway 2003, for the Norwegian Power Grid Company, Statnett, and their research test site in the mountains west of Oslo. The prototype was designed for a maximum ice load of 100 kg, and later it was modified for lower maximum loads (10, 25 or 50 kg). The ice that accretes on the vertical, freely rotating sensor (steel pipe with a surface area of 5 dm^2) – see Figure 3.1 - is weighed by a load cell, as the pipe is supported by a rod which is resting on the load cell. To avoid ice in the area for the bearing of the rod there is electrical heating of the bearing that is controlled with a thermostat. The output of the load cell is connected to a precision amplifier and converted into a standardized output current loop – 4 to 20 mA. To be able to perform testing of the instrument remotely there is a test relay included that will activate an electrical unbalancing of the load cell – at which the output signal will increase with 8 mA to indicate that acquired data are reliable.

To log data any kind of data logger with standardized current input (4 – 20 mA) can be used. At a Swedish sites in Åre the IceMonitor is connected to a monitoring station designed by SAAB Technologies (Figure 3.2). The Combi-Tech was tested in two forms at Deadwater Fell. Problems with instabilities in the electronics in the first winter meant that a Mark II version was installed for the second winter. A further modified instrument was not delivered in time to be tested in the 2008/09 winter.

Fig. 3.1 The Combi-Tech installed on the platform rails

Fig. 3.2 The IceMonitor on top of the ski-house at Åre (Sweden)

C. Goodrich/Rosemount Icemeter

The Rosemount ice detector uses an ultrasonically axially vibrating probe to detect the presence of icing conditions. The sensing probe is a nickel alloy tube mounted in the strut at its midpoint with one inch exposed to the air-stream. As the ice detector enters an icing environment, ice collects on the sensing probe. The added mass of accreted ice causes the frequency of the sensing probe to decrease in accordance with laws of classical mechanics. Ice detector software monitors probe frequency and detect this decrease. The ice signal activates at 0.52 mm ice accretion. At the same point the internal probe heater power is applied until the frequency rises to a predetermined set point. The probe is then heated to melt the ice. Once de-iced, the sensing probe cools within a few seconds and is ready to sense ice formation again. The ice detector outputs include ice detection indication and fault status indication. The icing rate is determined by the frequency of the heater de-icing. In operation at Deadwater Fell (Figure 3.3) it was also (and more effectively) logged according to the time actually spent de-icing over a 10 minute period.

Fig. 3.3 The Rosemount mounted on one of the wood pole supports of the platform at Deadwater Fell.

D. HoloOptic T20 series Icing rate sensor

All T20-series ice detectors are based on a patented digital optronic ice-indicator that indicates the presence of any type of atmospheric ice including clear ice. It comprises of a head with an IR emitter and a photo detector and a probe. The probe is mounted on a cylinder θ=30 mm L=500 mm. A single-direction T20-series indicator is sufficient if there is only one wind direction of interest and it is known (e.g. on a wind turbine nacelle). In all other cases the T20-series omni version is recommended and it is this type that was tested at Deadwater Fell (Figure 3.4). The sensors are equipped with a health-test which provides an early warning if the performance of a sensor is degraded. Icing is detected if more than 95 % of the probe is covered with a 50 µm thick layer of clear ice or 90 µm thick layer of other types of ice. As ice is detected, the internally controlled probe heating is turned on without time delay. After a short period of time the ice has melted and the water has fallen off the probe. The indication of icing will stop when the probe heating is turned off. The time interval between two indications may be as short as ten seconds. The time it takes to melt the ice is dependent on many factors (e.g. icing rate, air and surface temperature, melting power, wind speed and type of ice). Ice may start to build up on the probe again as the probe cools down. This cycle is repeated for as long as ice is created on the probe surface. If sufficient heating is applied, the time it takes for the probe to be covered with ice after it has been de-iced, is mainly dependent of the icing rate. The time between icing indications is used to calculate the icing rate.

Fig. 3.4 The HoloOptic sensor at Deadwater Fell

E. PMS Icemeter

The Czech PMS Icemeter is fully reported in another paper at this Workshop [2]. The rod on the icemeter is vertical (Figure 3.5) so that it can collect ice accretion from all directions. The vertical weight gives the ice load. Side pressure on the rod is used to monitor wind speed and direction. In all, the unit measures:

1. Ice load in kg/m;
2. Wind speed average;
3. Wind speed maximum;
4. Temperature;
5. Relative Humidity;
6. Wind direction;
7. Solar irradiance (external sensor).

Fig. 3.5 The PMS Icemeter at Deadwater Fell.

IV. Results

A. General

The results for the Combi-Tech, HoloOptic and Campbell/Rosemount are presented together in the following figures. Each figure shows the weather data, the conductor ice-loads and then the icemeter outputs. The PMS icemeter is recorded separately. There were times when the Combi-Tech rod could not rotate due to ice bridging the rod and its base (Figure 4.1).

Fig. 4.1 Ice bridging the Combi-Tech rod and base.

B. Combi-Tech, HoloOptic and Rosemount

There were 26 weather related incidents in the 2008/09 winter with peaks up to 62% increase in tension levels. Most incidents have been rime ice with some mix of rime and wet snow and a few completely wet snow incidents. Figures 4.1 to 4.8 show the entire winter data.

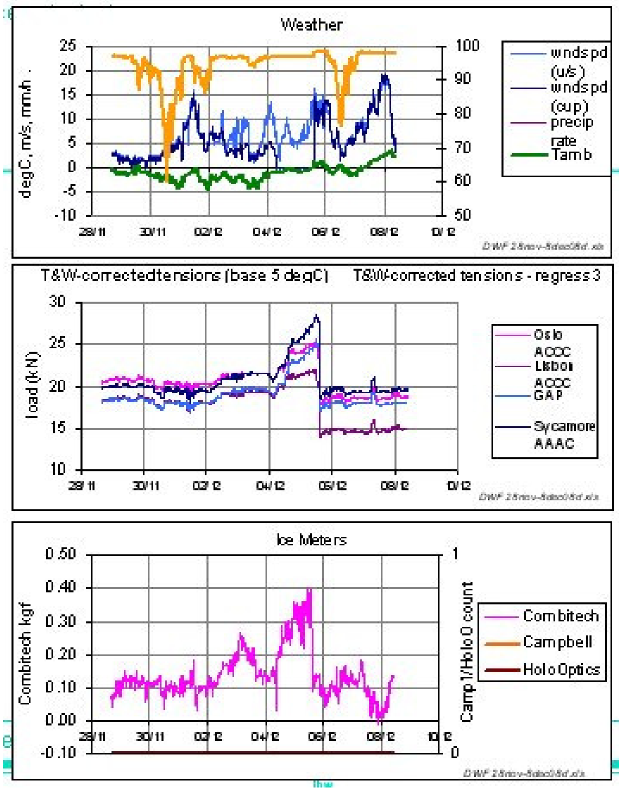

Fig. 4.2 Weather, conductor ice load and Icemeter data for early December, 2008. The Combi-Tech shows good agreement but no output from the other two icemeters.

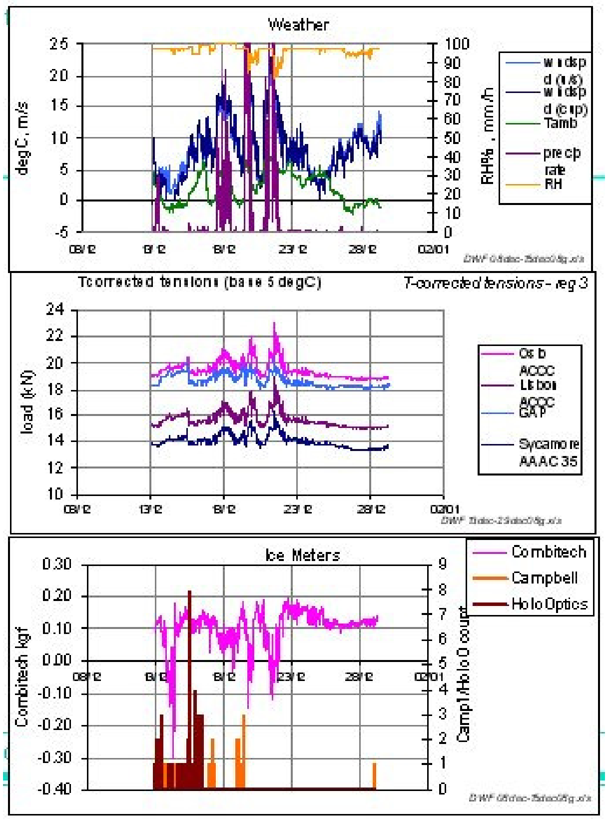

Fig. 4.3 Weather, conductor ice load and Icemeter data for late December, 2008. The Combi-Tech is inconsistent, the HoloOptics picks out one incident and the Campbell/Rosemount another.

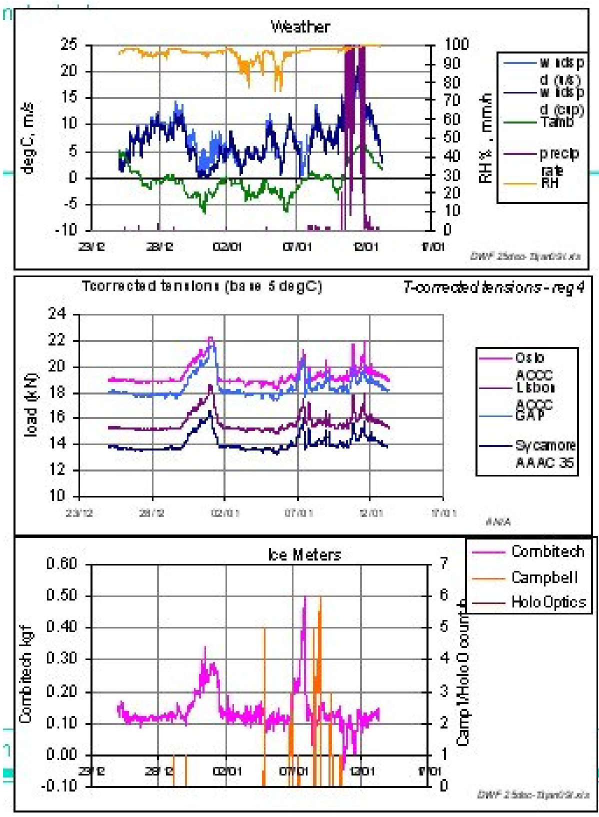

Fig. 4.4 Weather, conductor ice load and Icemeter data for early January, 2009. The Combi-Tech shows good agreement and the Campbell/Rosemount picks up the second incident but no output from the HoloOptic

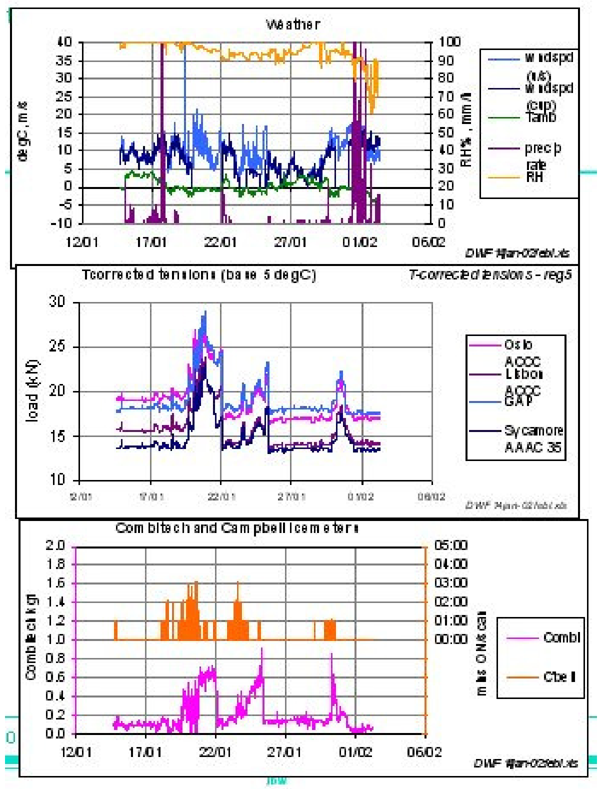

Fig. 4.5 Weather, conductor ice load and Icemeter data for late January, 2009. The Combi-Tech and Campbell/Rosemount show good agreement but no output from the HoloOptic

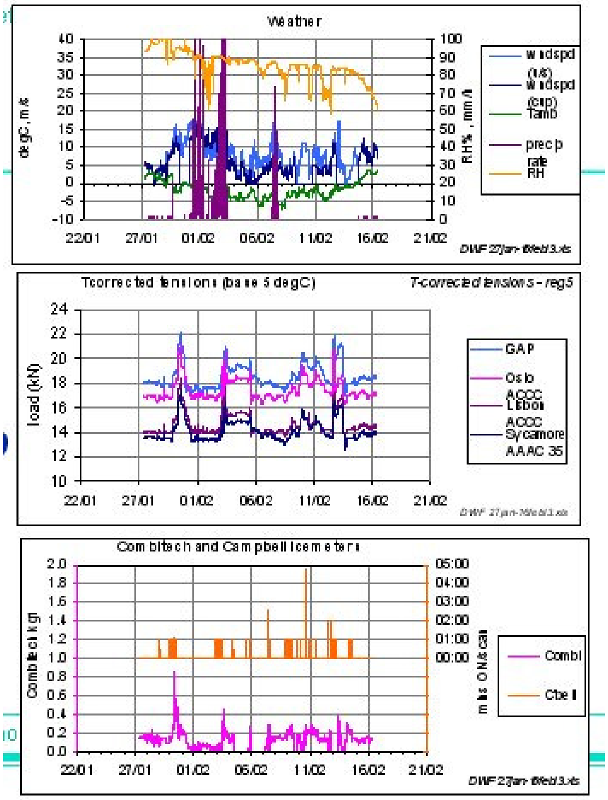

Fig. 4.6 Weather, conductor ice load and Icemeter data for early February, 2009. The Combi-Tech and Campbell/Rosemount show good agreement but no output from the HoloOptic

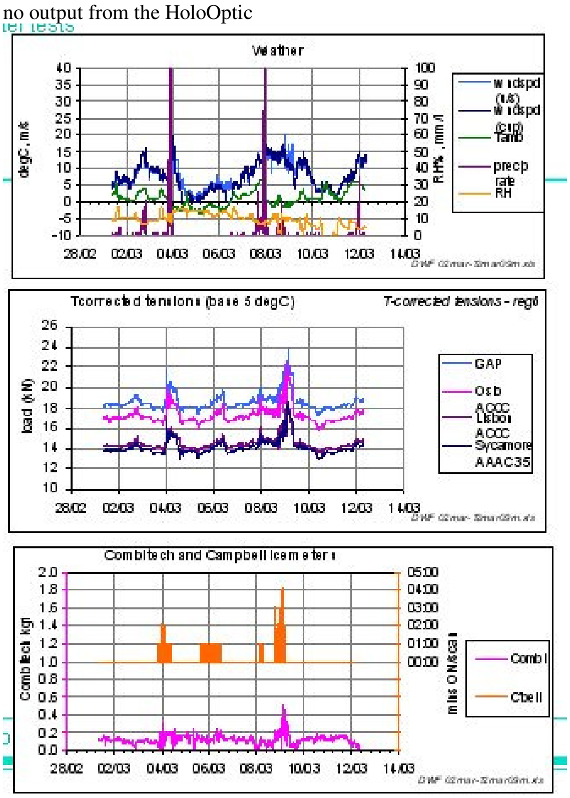

Fig. 4.7 Weather, conductor ice load and Icemeter data for early March, 2009. The Campbell/Rosemount shows good agreement but the Combi-Tech misses first two incidents and no output from the HoloOptic

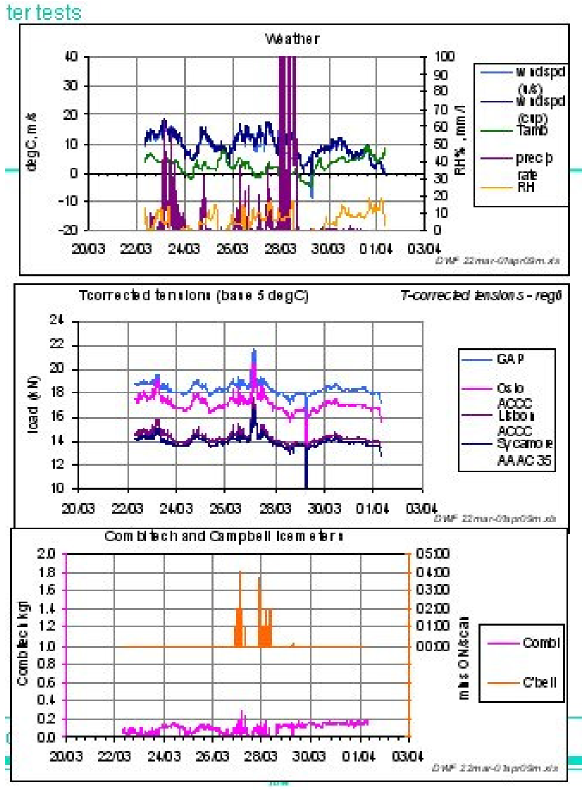

Fig. 4.8 Weather, conductor ice load and Icemeter data for late March, 2009. The Campbell/Rosemount shows good agreement but Combi-Tech barely indicates above noise level. No output from the HoloOptic

In summary, the Campbell/Rosemount performed best but the Combi-Tech was sometimes erratic and exhibited high noise levels. The HoloOptics failed due to mechanical damage early in the winter.

C. PMS Icemeter

The full data from the PMS Icemeter is given in another paper at this Workshop [2]. There was good agreement with the timing and intensity of icing incidents throughout the winter. There appeared to be no 'false positives' where icing is indicated but conditions are such that it could not have occurred. As the Icemeter is a vertical rod and so not directional, it indicates ice loads that would have occurred on any line normal to the wind and not just the ice load on the N-S span at Deadwater. As the monthly ice load data has already been given in [2] as well as the comparison of all meteorological data with the Deadwater instruments, only a summary of the whole winter is given here in Figure 4.9.

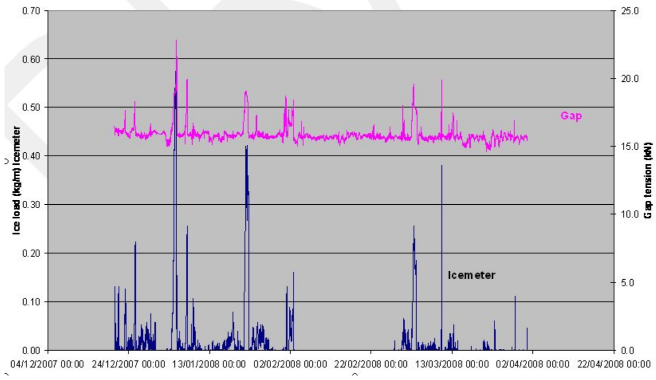

Fig. 4.9 The full winter's data for the PMS Icemeter comparing the tension level (temperature corrected) on the Gap conductor on the test span with indicated ice load output from the icemeter.

V. SUMMARY

The Deadwater Fell site has been used to compare actual measured wind/ice loads with the output from the Combi-Tech IceMonitor, Campbell/Rosemount Icemeter, the HoloOptic T20 series Icing rate meter and the Czech PMS Icemeter. The most consistent and accurate was the PMS instrument although the Rosemount also performed well. The HoloOptics failed early in the test period. The Combi-Tech was the only instrument specifically designed according to the recommendations in ISO 12494 but the output was erratic and noisy.

VI. REFERENCES

Papers Presented at Conferences (Unpublished):

[1] J. B. Wareing, "Deadwater Fell Test Site" presented at the 9th IWAIS, Andermatt, Switzerland, 2009. Poster PO. 067.
[2] J. B. Wareing and J Sabata, "Testing of the PMS icemeter at Deadwater Fell Test Site" presented at the 9th IWAIS, Andermatt, Switzerland, 2009. Poster PO. 069
[3] J. B. Wareing, "European Test Sites" presented at the 9th IWAIS, Andermatt, Switzerland, 2009.
[4] J. B. Wareing and B. E. Nygaard, "WRF model simulation of wet snow and rime icing incidents in the UK" presented at the 9th IWAIS, Andermatt, Switzerland, 2009.