Meteorological data for assessing climatic loads on overhead lines. Report from Cigré WG B2.28

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***Abstract*: Cigré has over the last decades published several reports on extreme weather actions, including loadings due to atmospheric icing, on electric overhead power lines. The last report was completed by WG B2.28 early 2015. For atmospheric icing the report describes a new approach for applying high resolution numerical meteorological weather prediction models where the cloud physics parameters are incorporated. Current operating test sites are presented, and some anticipated consequences of global climate change on icing are roughly discussed.**

Keywords: icing, wind, power lines, models, topgraphical influence, icing maps, icing measurements, climate change.

Legend and Abbreviations

Cigré	*International Council on Large Electric Systems*
SC B2	*Study Committee B2"Overhead Lines"*
WG	*Working Group*
IEC	*International Electrotechnical Commission*
NWP	*Numerical Weather Prediction model*
NNA	*National Normative Annex*

Introduction

The purpose of this report is to summarize new information relevant for assessing climatic loads on electric overhead lines. Such information has appeared in several publications from Cigré SCB2, as well as from other sources, after the publication of the Technical Report IEC 61774 "Overhead lines – Meteorological data for assessing climatic loads" in 1997 [1]. Later, Cigré WG B2.16 issued in 2006 the report "Guidelines for meteorological icing models, statistical methods and topographical effects" [2].

A new WG was set up by Cigré SC B2 in 2010 on "Meteorological data for assessing climatic loads. Update of IEC Technical Report (TR) 61774". According to its "Terms of Reference" WG B2.28 should: "compile and restructure updated meteorological knowledge for the purpose of application in international standards, especially on:

a) Turbulent wind enhancement behind steep terrain
b) Application of numerical weather prediction models
c) Measurements and observations of ice loads on overhead line components

Probably the most important reasons for reviewing meteorological data and assessment procedures concerning climatic loads and other adverse weather impacts on electric power overhead lines are the rapid developments in data availability for the atmosphere, better knowledge of physical processes relating to cloud physics and precipitation, and the capacities of modern computers. These factors have dramatically improved the reliability of modern weather forecasts. However, the same factors have also enhanced the ability to describe details in adequate weather parameters in local topography down to spatial scales relevant to the span length of electric power transmission lines, even in rough and complex terrain, by using standard NWPs.

Also, the concern on the effects of global warming due to anthropogenic emissions of greenhouse gases, mainly CO_2, has led to more specific attention on potential threats to electrical installations due to increased rates of extreme weather events, such as storms, floods, mud slides, rising sea level, foundations in melting permafrost, etc. A number of examples are given from many countries where pro-active mitigation actions are already taken or considered.

The final report from WG B2.28 is now in press [3]. This paper gives a short review of the part of the report with updated information on icing models, using weather forecasting models for the purpose of creating icing maps, and updated information on operating test sites for ice accretions.

Some anticipated effects from changes in the global climate on atmospheric icing, as well as a review of anti-icing and de-icing technologies are briefly mentioned.

A couple of wind issues are mentioned first however, as this may be relevant for wind on ice calculations.

I. Wind

Most common wind standards and design codes contain well accepted models for wind turbulence, therefore such models are not described in detail here. However, there are certain properties linked with some strong wind systems which are not always generally known or described in such wind codes. In particular this relates to vortex generation behind steep mountain sides. There are many examples that this kind of turbulence has occurred unexpectedly and caused damage to buildings and infrastructure in mountainous terrain.

A particular concern for wind engineering and overhead power line design has been the various transitions between wind gusts and mean winds of different averaging time for extra-tropical conditions. Therefore this aspect is analysed as well.

As these aspects are not a particular topic for IWAIS, the reader is instead referred to the Cigré WG B2.28 report [3].

II. Atmospheric icing

A. *A new approach to mapping of ice loadings*

Atmospheric icing is already described in detail in Cigré TB 291 "Guidelines for meteorological icing models, statistical methods and topographical effects" [2]. The current brochure [3] updates some information concerning ice load measurements and modelling, especially, of wet snow accretion, and the application of NWP models for analyses of wet snow and rime ice accretions on electric overhead line conductors. However, NWP models are so far only adequate for individual case studies. For long term extreme value calculations it is necessary to run the wet snow model on long time series of regular meteorological data from weather stations. For rime ice a NWP is the only way to study this phenomenon over a large area where no relevant data are available.

It has been found that the previously used accretion models for wet snow did not sufficiently explain a number of wet snow events in nature, in most cases the traditional model gave a systematic under-estimate of the actual wet snow loads. The model presented in this report is compared in particular with a great number of cases in Iceland where such loadings have been measured in great detail over many years. Therefore it was possible to revise the accretion model for wet snow on overhead lines to obtain a better fit with observations of such loads from the field.

Probably the biggest challenge with calculating ice loadings from any icing type is to obtain good quality input data. In the case of wet snow it is extremely important to ensure high quality measurements of precipitation. This may not be obvious in many cases, where, for instance, the “tipping bucket” method is used at regular weather stations. Snow measurements are always difficult as wind may blow the snow away from the gauge, even when it is equipped with a wind shield. But with a tipping bucket wet snow may accrete around the edge of the catchment part and hence disturb the catchment conditions for snow. Therefore such measurements must be given special attention.

In the case of rime ice there has been in principle no realistic way of getting “in situ” measurements of the fundamental cloud parameters like liquid water content and size distributions of cloud droplets, and indeed not from historic extreme rime ice events where the ice loadings should be re-analyzed. This situation has changed dramatically over the last years, when it has become possible to calculate such parameters from numerical models for the cloud atmosphere. In combination with digital information of the surface properties of the Earth, it has now become possible to calculate realistic high resolution values of rime icing in complex terrain by using advanced numerical weather prediction models.

As a demonstration of the potential of such modelling of both wet snow and rime ice, a recent map of ice loadings for Great Britain is presented in Figure 1. This map will be incorporated in the revision of EN 50341-1 [4] for the UK National Normative Annex (NNA). The inherent data in this map contains information on wet snow loads, rime ice loads and combined ice and wind loads, all provided in grid squares of 500 m x 500 m.

Wet snow loads are calculated with a return period of 50 years from regular weather stations. Due to the dense network of such stations in the UK it was possible to establish excellent correlation between individual stations and hence it was also possible to find good correlation functions with altitude and latitude over the whole UK.

In the case of rime icing a NWP model was run all through one selected winter season, and accordingly it was possible to identify relations with altitude and exposure for rime icing in the highlands. In order to evaluate rime ice loadings with a return period of 50 years standard procedures given in [4] were used. However, it was emphasized that whenever in the future new infrastructure should be built in these areas, a revision of the rime ice load assessments are strongly recommended.

If needed, other information, both meteorological and technical, can be gridded into the same system. The same grid boxes may contain other meteorological data, such as extremes for wind speeds, temperatures, snow depths on ground and lightning intensity. Also, they may contain operational and fault history of the overhead lines running through these grids.

In accordance with EN50341 requirements, the data is provided as wind only, ice only and combined wind and ice in the NNA.

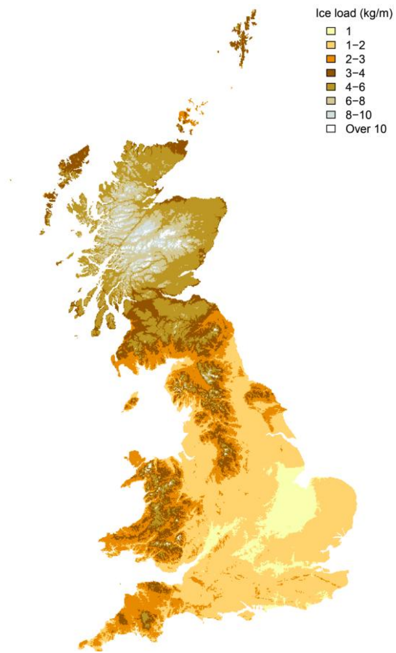

Figure 1. Combined wet snow and rime ice loading map for Great Britain

B. *Icing measurements*

Atmospheric icing is monitored and measured manually or automatically using various instruments as described in [5] and [6]. The only standard reference for icing measurements is given in ISO 12494 “Atmospheric icing on structures” [7]. According to this standard the overall design of the measurement device should be in principle as follows:

A cylinder with a diameter of 30 mm is placed with the axis vertical and slowly rotating around the axis. The cylinder length should be minimum 0.5 m, but if heavy ice accretion is expected, length could be 1 m. The cylinder is placed 10 m above terrain.

Measurements of icing and ice accumulations have been widely performed in many countries to collect information to be used for especially design of overhead power lines. As there have been no generally accepted standard or method for such measurements, most countries have designed their own systems, mostly as test spans or racks of various types. Such measurements are discussed in Cigré TB 291 [2].

- However, there are some general difficulties with such measurements, especially for remote places. There are multiple reasons for this:
- Icing comprises, by itself, a hostile environment for any type of instrument, especially those based on electronic sensing and recording
- Instruments for on/off-measurements of icing are not feasible for measuring accumulated loads, and vice versa
- The accretion rate of icing on any sensor depends strongly on the mechanical design of the sensor itself
- Each individual icing type sets limitations on the manner ice accretion can be measured
- The icing rate, or efficiency of droplet or snow collection, varies with the dimensions and shape of the accreted ice itself.

Several systems should be mentioned because of their systematic use and extensive data bases. These are

1. The “Passive Ice Meter (PIM)” as used in Canada
2. Test spans as used in Iceland
3. Measuring rigs used in Russia.

4. Also some operating test sites (as per 2014) are indeed important and mentioned (Iceland, Hawke Hill (Newfoundland, Canada), Deadwater Fell (UK)).

Further details on ice measurements in Europe (except Iceland) can be found in the State-of- art report from COST Action 727 “Atmospheric icing on Structures” [5].

The influence on rime icing from topography is emphasized in the report. This is particularly important along coastal areas dominated by significant mountain areas. A descriptive image of such effects on rime icing is presented in Figure 2.

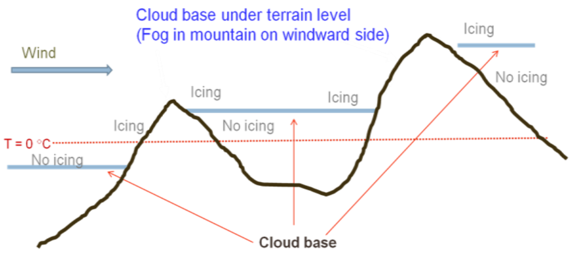

Figure 2. Schematic influence on cloud base and rime icing from upwind mountain topography.

A more comprehensive and detailed model for the macro-, meso- and microscale icing dependency of local and remote topography is developed in Russia and outlined in the report. The Russian procedures are here presented for the first time in English.

III. CHANGES IN GLOBAL CLIMATE

Although the question on climate change was not included in the tasks for this WG, some general comments are considered relevant for general information.

There are no longer any doubts that the global atmosphere is getting warmer mainly due to emissions of the greenhouse gases CO_2 and methane. This warming of the atmosphere will accordingly increase the total amounts of humidity in the atmosphere. But there is, at this point, very little evidence as to how this will in turn affect wet snow and rime ice loads for electric overhead lines. However, based on the available information on climate developments the following reasonings are found to be relevant for atmospheric icing in different areas:

- *Coastal areas*. As the sea temperature is also expected to rise, there may be fewer days of temperatures close to 0 °C along the coastal sides of continents, especially in northern latitudes. This may mean less frequency of wet snow incidents. However, higher intensity of short time wet snow precipitation may lead to higher loads when combined with low temperatures.
- *Continental inland*. Further inland from the coast where subfreezing temperatures are more frequent, higher wet snow loads in absolute values may be expected, although less frequent than at present. In predominant continental areas in northern latitudes the frequency and magnitude of wet snow loads are likely to increase.
- *Mountains*. In the mountain areas and continental highlands it is expected that the 0°C isotherm will be lifted on average, and hence lead to less frequent rime icing, at least at lower elevations. More humidity in clouds will contribute to higher rime ice loads whenever the conditions are favourable.
- *Extreme values*. It is not possible to make any sort of conclusions as to how the above arguments will influence the ice loadings with a given return period in local areas.
- For *freezing rain* there is at this point no strong indicator for significant change in either frequency or absolute load values following from the most likely scenarios for climate change.

However, a report published in 2014, from the Royal Society (UK) and National Academy of Sciences (US) [8], states:

Earth’s lower atmosphere is becoming warmer and moister as a result of human-emitted greenhouse gases. This gives the potential for more energy for storms and certain severe weather events. Consistent with theoretical expectations, heavy rainfall and snowfall events (which increase the risk of flooding) and heatwaves are generally becoming more frequent. Trends in extreme rainfall vary from region to region: the most pronounced changes are evident in North America and parts of Europe, especially in winter.

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